TM 11-6625-1606-15

TECHNICAL MANUAL

OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT,

GENERAL SUPPORT, AND DEPOT MAINTENANCE MANUAL

DUAL CHANNEL DC AMPLIFIER RECORDER

HEWLETT-PACKARD

MODEL 320 AND PAPER TAKEUP MODEL 320R-300

HEADQUARTERS, DEPARTMENT OF THE ARMY

NOVEMBER 1971

Information in this publication has been furnished under United States Government Contract No. DA28-043-AMC-01694(E) and shall not be either released outside the government, or used, duplicated, or disclosed in whole or in part for manufacture or procurement without the written permission of the Hewlett-Packard Corporation.

*TM 11-6625-1606-15

TECHNICAL MANUAL

NO. 11-6625-1606-15

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., 9 November 1971

Operator's, Organizational, Direct Support, General Support, and Depot Maintenance Manual

DUAL CHANNEL DC AMPLIFIER RECORDER

HEWLETT PACKARD MODEL 320 AND PAPER TAKE-UP MODEL 320R-300

CONTENTS

SECTION I

INTRODUCTION

	Paragraph	Page
Scope	1-1	1-1
Indexes of Publications	1-2	1-1
Forms and Records	1-3	1-1
Items Comprising An Operable Equipment	1-4	1-1
General Description	1-5	1-2
Performance Data	1-6	1-3
Front Panel Data (Each Channel)	1-7	1-6

*This technical manual is an authentication of the manufacturer's commercial literature and does not conform with the format and content specified in AR 310-3, Military Publications. This technical manual does, however, contain available information that is essential to the operation and maintenance of the equipment.

SECTION 2

INSTALLATION AND OPERATION

	Paragraph	Page
Unpacking and Inspection	2-1	2-1
Power Connection	2-2	2-1
Operating Position	2-3	2-1
Chart Loading	2-4	2-2
Operational Check	2-5	2-6
Signal Connection	2-6	2-8
Recording	2-7	2-10
Low Level Electrical Phenomena	2-8	2-11
Monitoring	2-9	2-11

SECTION 3

MAINTENANCE

Introduction	3-1	3-1
Power Fuse Replacement	3-2	3-1
Writing Arm Maintenance	3-3	3-2
Frequency Compensation and Damping Adjustments	3-4	3-6
Parallax Correction	3-5	3-7
Paper Tension and Tracking Adjustment	3-6	3-8
Case Removal	3-7	3-9
Inspection	3-8	3-10
Calibration Cell Replacement	3-9	3-10
Lubrication Requirements for Paper Take-up	3-10	3-11
Assembling the Paper Take-up Spindle	3-11	3-12
Supply Voltage Adjustment	3-12	3-13
Transistor Replacement	3-13	3-13
Trouble Shooting Hints	3-14	3-14
Instructions for Troubleshooting	3-15	3-15
Precautions to Be Observed When Using Paper Take-up	3-16	3-16
Printed Wiring Board Techniques	3-17	3-17

SECTION 4

CIRCUIT THEORY

	Paragraph	Page
Introduction	4-1	4-1
General	4-2	4-1
Common-mode (in-phase) Signals	4-3	4-2
Guard Shield Theory	4-4	4-3
Input	4-5	4-5
Input Amplifier	4-6	4-6
Gain and Range Controls	4-7	4-6
Three-Stage Amplifier	4-8	4-6
Position Control	4-9	4-7
Demodulator and Filter	4-10	4-7
Limiter	4-11	4-8
Dual Amplifier	4-12	4-8
DC Amplifier and Output Stage	4-13	4-9
Galvanometer	4-14	4-9
Power Supply	4-15	4-11
Voltage Regulator and oscillator	4-16	4-12
Trouble Shooting Hints	4-17	4-12

APPENDIX A. REFERENCES A-1

B. MAINTENANCE ALLOCATION B-1

ILLUSTRATIONS

	FIGURE NO.	PAGE
Dual Channel DC Amplifier Recorder, Model 320	1-1	1-0
Operating Positions	2-1	2-2
Paper Loading in Sanborn "320" Series of Recording Instruments	2-2	2-3/-4
Direction of Paper Feed	2-3	2-5
Blue Terminal Assembly Properly Inserted Into the Connector Shell	2-4	2-8
Power Fuse Location	3-1	3-1
Writing Arm Adjustments	3-2	3-2
Stylus Pressure Tester, Model 442	3-3	3-3
Writing Arm Pressure Test	3-4	3-4
Damping Adjustment Wave Forms	3-5	3-7
Transistor Assembly	3-6	3-13
Component Removal Technique	3-7	3-17
Differential Amplifier	4-1	4-2
Method of Changing a Common Mode Signal Into a Differential Signal	4-2	4-3
Guard Shield Circuit	4-3	4-4
Equivalent Circuits	4-4	4-5
Basic Demodulator Circuit	4-5	4-7
Electrical Galvanometer Damping	4-6	4-10
Regulator Card Assembly Model 320-100-C12	4-7	4-13
Regulator Card Assembly Model 320-100-C24	4-8	4-14
Recorder Model 320, Front View	4-9	4-15/16
Recorder Model 320, Right Side View	4-10	4-15/16
Recorder Model 320, Right Side View	4-11	4-17/18

	Figure No.	Page
Switch Assembly 320-100-C3	4-12	4-17/18
Right Cal Assembly 320-100-C10	4-13	4-17/18
Timer Assembly (50 Cycle, 60 Cycle)	4-14	4-19/20
Recorder Brake Roll Assembly 320-100-C20	4-15	4-19/20
Clutch Actuator Assembly 320-100-C27	4-16	4-19/20
Galvanometer Assembly Sanborn Number 6080	4-17	4-21/22
Galvanometer Assembly Sanborn Number 607	4-18	4-21/22
Galvanometer Assembly (Insert) 606	4-19	4-23/24
Recorder, Model 320, Top View	4-20	4-23/24
Recorder, Model 320, Left Side View	4-21	4-25/26
Recorder, Model 320, Back View	4-22	4-25/26
Recorder Assembly	4-23	4-27/28
Upper Right Chassis Assembly	4-24	4-29/30
Upper Left Chassis Assembly	4-25	4-29/30
Sanborn Dual Channel DC Amplifier, Recorder Model 320, Bottom View	4-26	4-29/30
Diode Mounting Board Assembly (E4)	4-27	4-31/32
Accessories Supplied With Sanborn Recorder, Model 320	4-28	4-31/32
Medium Gain Preamplifier Card 950-3400	4-29	4-31/32
Regulator Card 321-100-C10	4-30	4-33/34
Printed Circuit Assembly 320-100-C30	4-31	4-33/34
Stylus Mounting Adapter 613-100-C7	4-32	4-33/34
Lower Right Chassis Assembly 320-100-C6	4-33	4-33/34
Coil and Stylus Holder Assembly 608D-100-C3	4-34	4-33/34
Galvanometer Coil Assembly 606-100-C2	4-35	4-33/34
Sanborn Dual Channel DC Amplifier Recorder, Models 320, 320T. Schematic: 320-100-C1 Sub 34	4-36	4-35/36

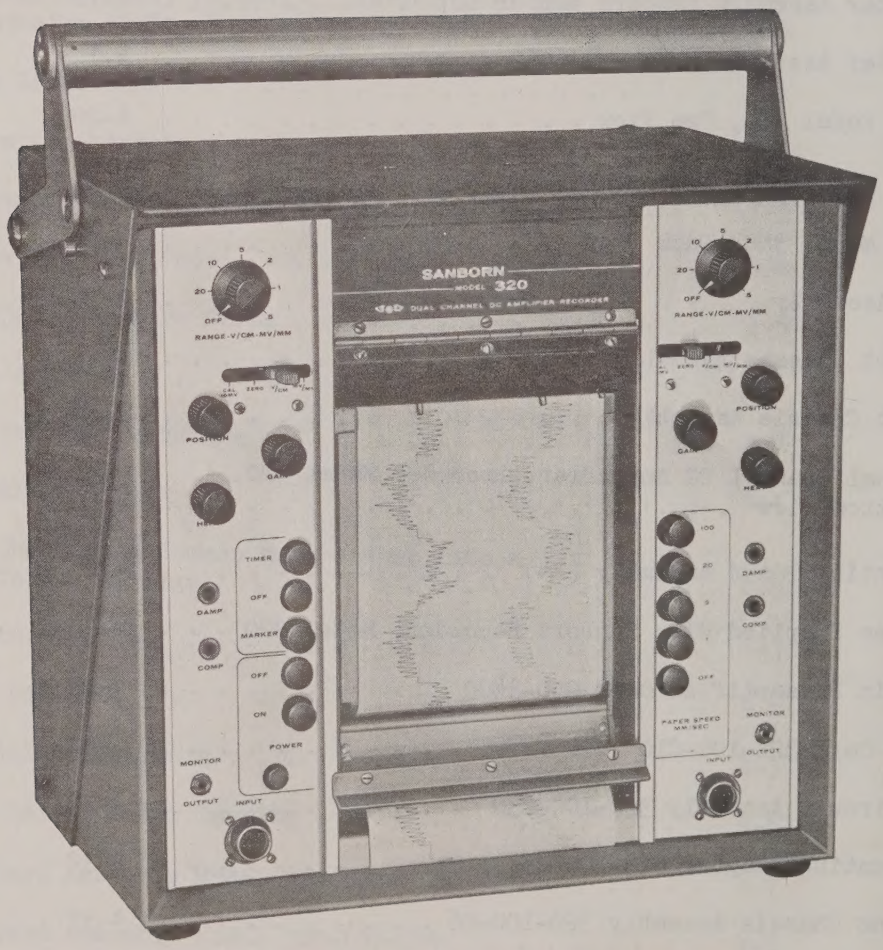


FIGURE 1—1. DUAL CHANNEL DC AMPLIFIER RECORDER, MODEL 320

SECTION I
INTRODUCTION

I—1. SCOPE

This manual includes installation and operation instructions and covers operator's, organizational, direct support (DS), general support (GS) and depot maintenance. It describes Hewlett-Packard (Federal Supply Code Dual Channel DC Amplifier Recorder Models 320, 320R, 320T, 320TR, 320TX, 320X and 320XR, and Paper Take-up Model 320R-300.

I—2. INDEXES OF PUBLICATIONS

a. Refer to the latest issue of DA Pam 310-4 to determine whether there are new deitions, changes, or additional publications pertaining to this equipment.

b. Refer to the latest issue of DA Pam 310-7 to determine if there are current, applicable modification work orders (MWO's) pertaining to this equipment.

I—3. FORMS AND RECORDS

a. Report of Maintenance and Unsatisfactory Equipment. Use equipment forms and records in accordance with instructions in TM 38-750.

b. Reports of Packaging and Handling Deficiencies. Fill out and forward DD Form 6 (Report of Packaging and Handling Deficiencies) as Prescribed in AR 700-58 (Army), NAVSUP Publication 378 (Navy), AFR 71-4 (Air Force), and MCO P4610-5 (Marine Corps).

c. Discrepancy in Shipment (DISREP) (SF361). Fill out and forward Discrepancy in Shipment Report (DISREP) (SF361) as prescribed an AR 55-38 (Army), NAVSUP Pub 459 (Navy), AFM 75-34 (Air Force), and MCO p4610.19 (Marine Corps).

d. Reporting of Equipment Manual Improvements. Report of errors, omissions, and recommendations for improving this manual by the individual user is encouraged. Reports should be submitted on DA Form 2028 (Recommended Changes to DA Publications) and forwarded direct to: Commanding General, U.S.Army Electronics Command, ATTN: AMSEL-ME-NMP-EM, Fort Monmouth, New Jersey 07703.

I—4. ITEMS COMPRISING AN OPERABLE EQUIPMENT

FSN	Item	Quantity	Height (in)	Depth (in)	Width (in)	Weight (lb)
5895-420-9161	Dual Channel DC Amplifier Recorder Hewlett-Packard Model 320	1	13-3/4	9-3/4	14	55
5895-420-5173	Paper Take-up Hewlett-Packard Model 320R-300					

I—5. GENERAL DESCRIPTION

The Dual Channel DC Amplifier Recorder is a two-channel recording system, designed for general purpose d-c recordings. Each channel is a stable, high-gain carrier amplifier which incorporates the dependability of transistor electronics with easily serviced printed-wiring plug-in boards. The input circuits are isolated from ground and include a guard shield, providing accurate recording in the presence of high common-mode voltages, with complete inter-channel isolation.

The system is contained in a heavy-duty carrying case with combination carrying handle and adjustable stand This feature permits positioning the instrument for recording either vertically, horizontally, or at an angle of 20 degrees

Inkless recordings are made by hot-wire writing arms on heat-sensitive Sanborn Permapaper chart, for fast accurate recording on true rectilinear coordinates. Approximately six inches of Permapaper chart is visible at all times for viewing the record as it is being made. Notes may be written directly on the Permapaper, using pencil, pen, or ballpoint pen. The four-speed chart drive is controlled by front panel push-buttons, and provides a wide range of recording speeds from 1 millimeter per second to 100 millimeters per second. A marker arm in the right margin of the chart, with an internal one-second timer, provides both coding and time indications for precise identification of recorded data. In addition to the output indicated by the recording galvanometers, an auxiliary front panel output jack is available for each channel and may be used to monitor the recording with an external indicating device such as an oscilloscope.

Dual Channel DC Amplifier-Recorder, Model 320 and 320T, use a printed circuit plug-in regulator board. The three models are identified as follows:

Model 320-100-C12	1200 cycle oscillator
Model 320-100-C24	1200 cycle oscillator
Model 321-100-C10	2400 cycle oscillator

I—6. PERFORMANCE DATA

Channels:	Two-channel recording, each channel 5.0 centimeters wide.
Dimensions:	Approximately 13-3/4" long, 14" wide, and 9-3/4" deep.
Weight:	55 pounds.
Power Requirements:	103 to 127 volts, 60 cycles, single-phase, approximately 100 watts.
Recording Speeds:	1, 5, 20, and 100 millimeters/second.
Sensitivity:	0.5, 1, 2, 5, 10 and 20 millivolts/millimeter and volts/centimeter, corresponding to 25, 50, 100, 250, 500 millivolts, 1, 2.5, 5, 10, 25, 50 and 100 volts edge to edge of the 50 millimeter recording chart. A smooth gain control permits adjustment of range from 2-1/2 to 1".
Input Impedance:	0.5 megohm on millivolt ranges, 1.0 megohm on volt ranges, floating and guarded with inter-channel isolation. Source resistance should be below 10,000 ohms on millivolt ranges only.
Frequency Response:	DC to 125 cycles within 3 db at 10 millimeters peak-to-peak amplitude. DC to 50 cycles within 3 db at 50 millimeters peak-to-peak amplitude.
Response Time:	5 milliseconds maximum from 10% to 90% of final deflection; overshoot 4% or less.
Noise:	0.25 millimeter peak-to-peak maximum at calibrated gain.
Common Mode Voltage Tolerance:	±500 volts maximum.

I—6. PERFORMANCE DATA (Continued)

Common Mode Rejection:	140 db minimum at d-c; 120 db minimum at 60 cycles with no input unbalance; 100 db minimum at 60 cycles with 5000 ohms unbalance.
Drift:	0.25 millimeter maximum as a function of 10°C ambient temperature change in the range of 0°C to 40°C; 0.1 millimeter maximum as a function of line voltage variation from 103 to 127 volts.
Gain Stability:	Better than 1% with ambient temperatures from 0°C to 40°C; better than 1% with line voltage changes from 103 to 127 volts.
Limiting:	Electrical, approximately 115% of full scale.
Calibration:	10 millivolts ±2% , internal.
Monitor Output:	Approximately 40 millivolts/millimeter deflection across at least 0.1 megohm load.
Linearity:	Maximum non-linearity 0.25 millimeter.*

*Sanborn Company measures and defines linearity as follows:

a. Adjust zero-signal stylus position to mid-chart. Then apply DC signal for a 20-division up-scale stylus deflection. Measure amplitude of this DC signal carefully, in terms of input signal voltage.

b. Now apply, in order, 0%, 25%, 50%, 75%, 100%, and 125% of the DC signal applied in step a.

c. Now apply the same series of signals, with opposite polarity.

d. Look for stylus deflections which almost exactly coincide with the heavy lines every five divisions on the chart. Deflections should coincide exactly at mid-scale and at +20 divisions. Linearity error is the distance on the chart by which each actual deflection misses its heavy line.

Note: to avoid hysteresis effects, perform test at a high paper drive speed.

I—6. PERFORMANCE DATA (Continued)

UNIT IDENTIFICATION:

Model 320R is a rack mounted Model 320 Recorder. Model 320T, 320TR is a medical version of the Model 320 with paper speeds of 2.5, 5, 25, and 50 mm/sec. Model 320TR is a rack mounted Model 320T. Model 320X, 320TX, and 320XR have been designed to operate from 50 cycle, 115V or 230V source. A switch located at the rear of the unit provides the means of selecting the desired voltage. The X indicates that the recorder is an export version of the standard model.

I—7. FRONT PANEL DATA (EACH CHANNEL)

RANGE V/CM-MV/MM:	Multi-position rotary switch to attenuate the signal by fixed factors.
POSITION:	Control for adjusting the position of the writing arm on the recording chart.
CAL-ZERO-V/CM-MV/MM:	Four-position function switch which determines the operating mode of the amplifier.
GAIN:	Control for setting the gain of the amplifier so that the sensitivity values stated on the RANGE switch are accurate, and for providing intermediate sensitivities.
HEAT:	Control for adjusting the heat of the writing arm stylus for adequate trace density.
DAMPING:	Screwdriver-adjusted control for setting the damping of the galvanometer.
COMPENSATION:	Screwdriver-adjusted control for compensating for the loss in galvanometer response at high frequencies.
MONITOR OUTPUT:	Miniature jack to provide output signals for monitoring devices.
INPUT:	3-contact (2 contacts guarded) male connector.
Controls common to both channels:	
POWER-TIMER-MARKER:	Series of five push-button switches at the left side of the panel for applying power, starting the one-second timing motor, or marking the recording.
PAPER SPEED:	Series of five push-button switches at the right side of the panel for selecting the recording speed.
INDICATOR:	Lights when power is applied.

SECTION 2

INSTALLATION AND OPERATION

2—1. UNPACKING AND INSPECTION

Remove the recorder from its packing case and place on a table, bench top, or other firm, flat support. Inspect the equipment for any damage incurred during transit. If the equipment has been damaged, refer to paragraph 1-3.

2—2. POWER CONNECTION

Most recorders of this model operate at 115 volts, 60 cycles, which is standard through most of the United States. Check the nameplate at the rear of the recorder before connecting to a power outlet; be sure that the line voltage and frequency are the same as that stamped on the nameplate.

(Special recorders are designed for 220/250 volts, 50 or 60 cycles; use these with the corresponding electric power. Do not use any recorder on d-c or 25 cycle a-c power lines.) Before connecting the recorder to the power line, press down on the push-button POWER OFF switch.

The power cord is stored in the carrying handle when not in use. Remove it and note the three-terminal plug at the end of the cord. This plug may be used directly on power outlets where a three-wire system is used. If the power system is of the two-wire type, use the three-wire adapter plug (accessory) between the power cord plug and the power outlet. Connect the short green lead of the adapter to a suitable ground.

2-3. OPERATING POSITION

The recorder may be used in a vertical or horizontal position, or at an angle of 20 degrees, with no effect on the operation of the instrument.

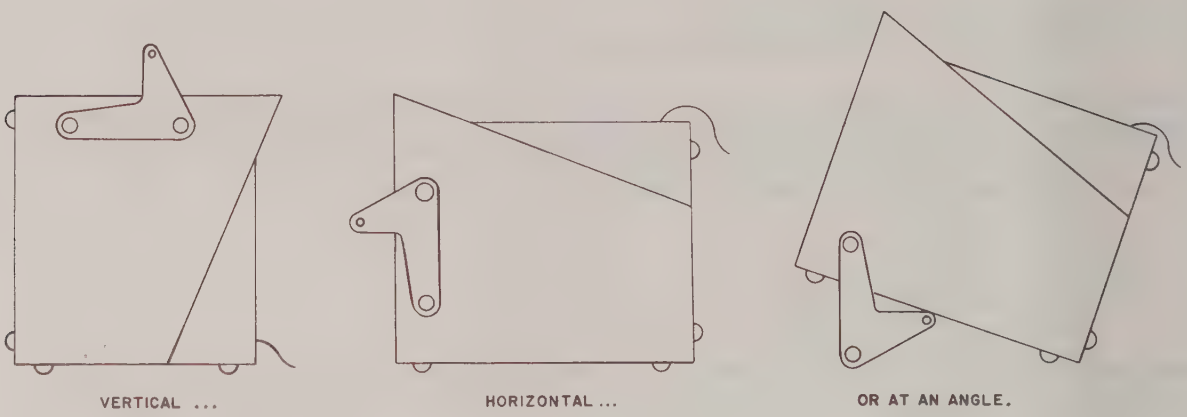


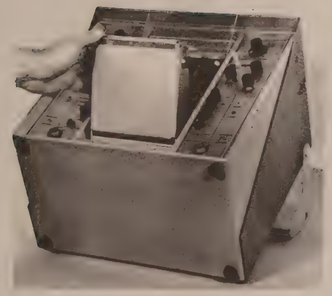
Figure 2-1. Operating Positions

The latter position is ideally suited for bench or table top use, if the operator is seated. The recorder may be placed in this position by releasing the catch at each side of the carrying handle, then rotating the handle backwards, so that it supports the back of the case.

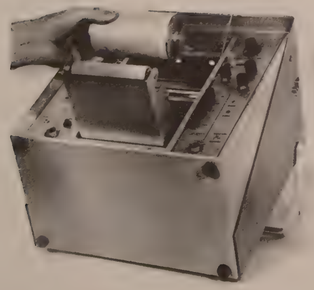
2-4. CHART LOADING

Sanborn Permapaper chart used in this recorder is supplied in 200 foot rolls. Charts printed with green coordinates are usually used in industrial applications; charts printed with black coordinates are usually used in medical applications. Special Translucent Permapaper is available and is suitable where Ozalid reproduction of the recording is desired. Each roll of Permapaper is marked with a star, 30 feet from the end of the roll, and serves as a warning to the operator that the paper supply is nearing exhaustion. Permapaper is installed in the recorder by following the illustrations a. through c. in Figure 2-2.

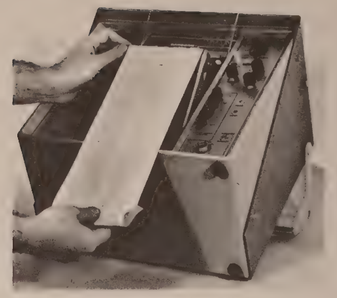
a. Turn the instrument off. Rotate the carrying handle beneath the case so that the recorder rests at a 20 degree angle. Lift the plastic viewing window up and push the writing table lock lever toward the galvanometers, releasing the table and lifting the writing arms from the writing edge.



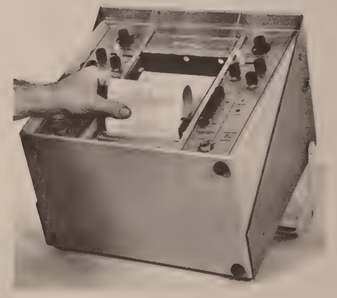
b. Lift the paper table up and toward the operator. If the paper supply is not completely exhausted, roll the remaining paper back on to the roll. Lift the paper roll out of its brackets and away from the paper drive compartment.



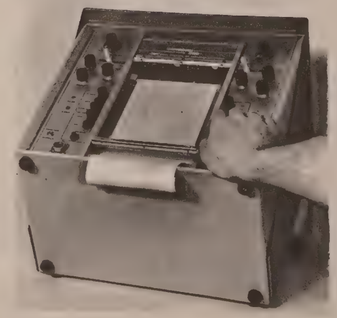
c. Remove the spool by pulling the left hand end disc out of the paper roll, then pull the paper roll core off the spindle. Place the new roll over the spindle. When installed, paper should leave the roll so that the grid lines of the chart are visible when pulled over the writing edge. Press the left end disc into the paper roll. Place the loaded spool in its mounting bracket, removable end disc to the left.



d. Pull the leading edge of the paper over the rubber brake roll and the writing edge. Now, lower the paper table into place, keeping the paper as taut as possible over the writing edge to keep from entangling the writing arms. Pull the lock lever back toward the operator.



e. Fold the leading edge of the paper. Set the paper speed to 20 mm/second and start the motor. Feed the end of the paper down in between the drive roll guard plate and the end of the table. The drive roll will pick up the paper and carry it through, appearing at the other side of the guard plate and between the plate and the metal idler roller.



f. When the paper feeds satisfactorily, shut the drive motor off and lower the viewing window into place.

Figure 2-2.

PAPER LOADING IN SANBORN "320" SERIES OF RECORDING INSTRUMENTS

2—4. CHART LOADING (Continued)

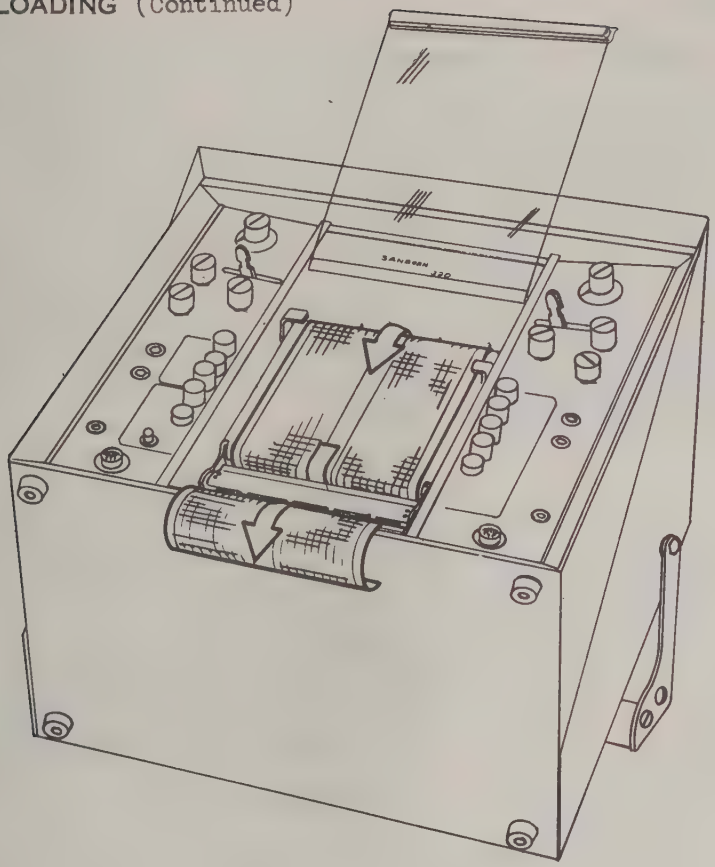
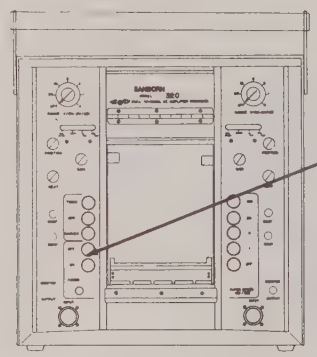


Figure 2-3. Direction of Paper Feed

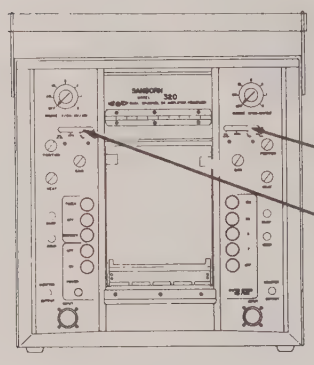
2—5. OPERATIONAL CHECK

The following tables present the most frequently used controls in the logical order of their use.



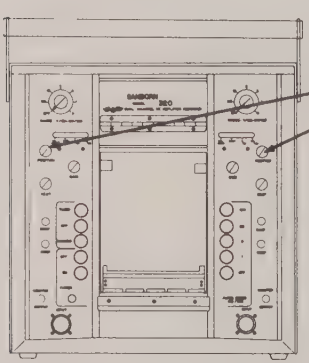
POWER ON-OFF:

Press the push-button POWER "ON" switch; the red indicator should light. Allow approximately five seconds for the amplifiers to stabilize before making other adjustments.



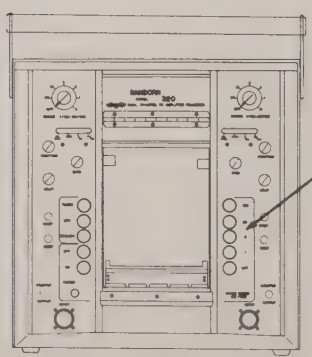
CAL-ZERO-V/CM-MV/MM:

Set the lever switches of both channels to ZERO. This permits setting the no-signal position of the writing arm.



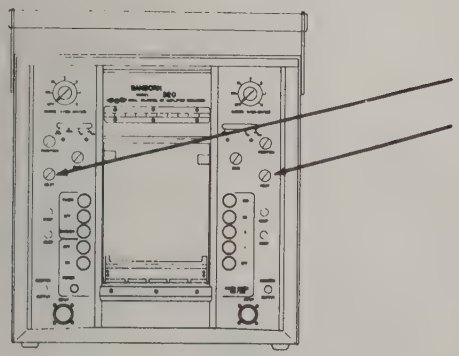
POSITION:

Turn the POSITION controls back and forth while watching the writing arms. It should be possible to move each arm over the entire width of its channel. Adjust the controls to place the arms in the center of each channel.



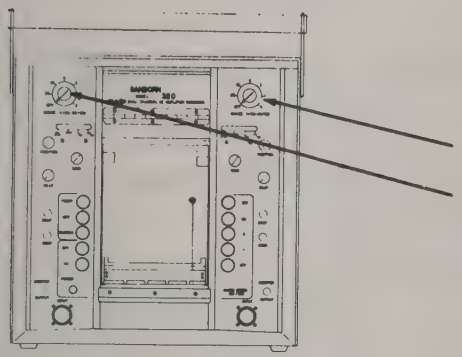
PAPER SPEED:

Press the 1 MM/SEC push-button switch; the paper should feed slowly out of the recorder. Next, press the 5, then the 20 and finally the 100 MM/SEC push-buttons; the paper speed should increase with each step. Return the paper speed to 5 MM/SEC.



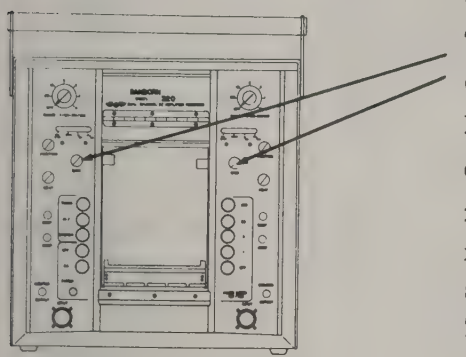
HEAT:

Turn the HEAT controls for both channels to each extreme while watching the baseline formed by the heated stylus. Adjust the controls for a firm, dense black baseline, with clear well-defined edges. Maximum stylus heat control settings should be used when recording frequencies in the middle to high frequency range of the recorder frequency response characteristics.



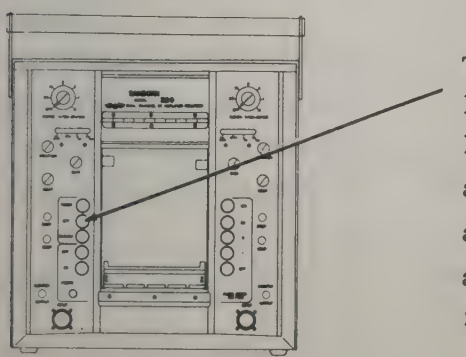
RANGE V/CM-MV/MM:

Rotate the RANGE switches fully clockwise to .5. This is the maximum sensitivity position of these controls.



GAIN:

Turn the GAIN controls of both channels fully counter-clockwise and set the CAL-ZERO-V/CM-MV/MM switches to CAL. Each writing arm will deflect approximately 10 mm. to the left. Slowly rotate the GAIN controls until the writing arms indicate exactly 20 mm. deflection. Record a series of square-waves by switching the CAL-ZERO-V/CM-MV/MM controls between CAL and ZERO.



TIMER-MARKER:

Press the MARKER button; a continuous power line frequency signal will be traced by the marker arm. Now, press the TIMER button; the marker arm will pulse at one-second intervals. Marking and timing may be done simultaneously by pressing both TIMER and MARKER buttons.

2-6. SIGNAL CONNECTION

This recorder includes a guard shield in the input circuit to obtain high common-mode rejection. Signals are connected to the front panel INPUT connector using the table below. After attaching signal leads, reassemble the mating connector for the INPUT socket by inserting the blue terminal assembly into the connector shell so that terminal M and C are next to the key plate, as shown in Figure 2-4. This allows the internal key to mate with the terminal assembly keyway.

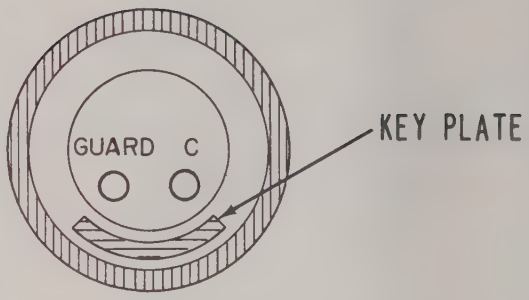
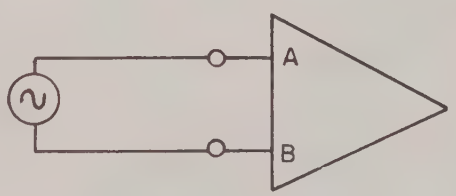
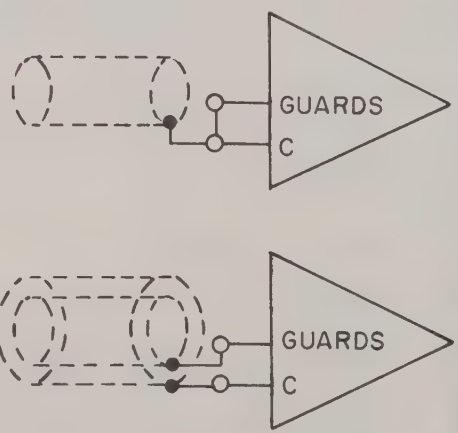
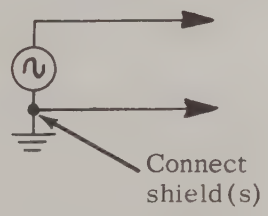
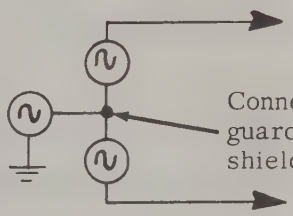
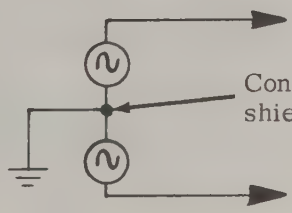
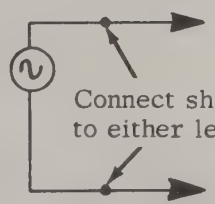
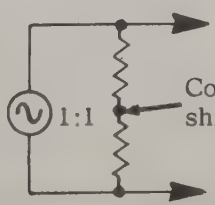


Figure 2-4. Blue Terminal Assembly Properly Inserted Into the Connector Shell

<table>
<tr><td>1. Connect the input signal . . .</td><td> 
</td><td colspan="3"><table>
<tr><th>When terminal "A" is:</th><th>and terminal "B" is:</th><th>then deflection is:</th></tr>
<tr><td>+</td><td>—</td><td>up-scale</td></tr>
<tr><td>—</td><td>+</td><td>down-scale</td></tr>
</table></td></tr>
<tr><td>2. . . . then connect the shield(s) . . .</td><td> 
</td><td colspan="3">Terminal C is the ground terminal; it always connects to the outer shield of the cable.
The remaining terminals are the guard shield terminals; one of these terminals always connects to the inner (guard) shield, or connects to terminal C if no guard shield is used.</td></tr>
</table>

2—6. SIGNAL CONNECTION (Continued)

3. and finally, connect the shield(s) at the signal source.		Single-ended input, one side grounded.
		Balanced input in presence of common-mode component.
		Balanced input with no common-mode component.
		Floating input. Connect shield(s) to either signal leg or connect a 1:1 divider across the signal legs and connect shield(s) at mid-point. Resistors should be matched to within 1%.
		

2—7. RECORDING

After making the proper power and signal connections, turn the recorder on and adjust the POSITION controls to center the writing arms on the chart. Calibrate the recorder by setting the RANGE switches to .5 and the CAL-ZERO-V/CM-MV/MM switches to CAL, then adjust the gain controls for exactly 20 millimeters of writing arm deflection. Return the RANGE switch to OFF and set the CAL-ZERO-V/CM-MV/MM switches to V/CM.

Turn the recorder PAPER DRIVE on at the desired recording speed and slowly rotate the RANGE switches clockwise. If the writing arm deflections are too small for accurate interpretation at any setting of the RANGE switch, return this switch to OFF and set the CAL-ZERO-V/CM-MV/MM switches to MV/MM. Rotate the RANGE switches clockwise until the desired deflections are obtained. (Input voltage required for full scale deflection at any setting of the RANGE switch is given in the table below.) To mark or time the recording, press the appropriate push-button.

WARNING:

Do not apply over 50 volts (differential) to the input terminals on the MV/MM range or over 500 volts (differential) on the V/CM range. Common-mode voltage tolerence at all positions is ±500 volts.

RANGE (V/CM)	VOLTS FOR FULL SCALE DEFLECTION AT CALIBRATED GAIN
.5	2.5 volts
1	5 volts
2	10 volts
5	25 volts
10	50 volts
20	100 volts
RANGE (MV/MM)	**MILLIVOLTS FOR FULL SCALE DEFLECTION AT CALIBRATED GAIN**
.5	25 millivolts
1	50 millivolts
2	100 millivolts
5	250 millivolts
10	500 millivolts
20	1000 millivolts

2—8. LOW LEVEL ELECTRICAL PHENOMENA

When measuring extremely low voltages, stray potentials in the external circuit may prevent full use of the amplifier's abilities. These potentials appear on the record or at the MONITOR OUTPUT as a signal which is difficult to distinguish from the value being measured, or as a signal which obscures the value being measured, or as a baseline shift when the RANGE switch is turned.

If the effects of stray potentials are too large to be ignored, one or more of the following procedures will usually reduce the disturbance to manageable proportions:

a. Magnetic coupling can be reduced or eliminated by using an input cable whose conductors are twisted, by reducing the area of any conductor loops in the signal circuit, by isolating the input circuit from varying magnetic fields, or by magnetic shielding of the signal circuit.

b. Capacitive coupling can be controlled by careful static shielding, that is, enclosure of leads in a metallic sleeve which is connected to guard or ground.

c. Any impedance in the input circuit which is common to the input circuit and to some other circuit which carries a current (such as the earth, or a common ground bus, or a structural member used as ground) can introduce a stray signal into the input circuit. This can be reduced or eliminated by proper guarding and grounding.

d. Thermo-electric effects are a common source of stray potentials which must be avoided when operating at high sensitivities. These may be reduced by avoiding contacts which are of dissimilar metals, and by keeping all contacts clean. The entire external circuit should be kept at a uniform temperature.

2—9. MONITORING

Recordings can be monitored with an oscilloscope or other high impedance indicating device by connecting to the front panel MONITOR OUTPUT jack, using the mating connector supplied as an aceessory. The source resistance is 10,000 ohms. A load resistance of one megohm will change recorder calibration by 1%. Lower load resistances will require recalibration. Approximately 40 millivolts/millimeter of deflection is available.

SECTION 3

MAINTENANCE

3—1. INTRODUCTION

This section of the instruction manual provides the operator or repair technician with maintenance procedures for this instrument. All adjustments described in this section are factory set.

3—2. POWER FUSE REPLACEMENT

Primary power is supplied to the recorder through a single power fuse, located at the back of the case, near the power cord. To install a new fuse place the recorder in its vertical operating position and rotate the fuse cap one-half turn to the left, then lift out. Replace the open fuse with a 1.0 ampere slow-blow fuse (Bussman F02G1R00A). If the fuse continues to open after installing a replacement, inspect the recorder for wiring shorts, faulty components, etc.

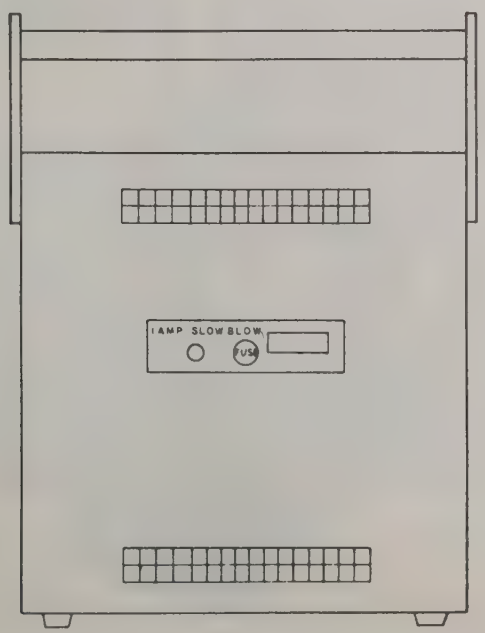


Figure 3-1. Power Fuse Location

3—3. WRITING ARM MAINTENANCE

This recorder uses three writing arms: the two galvanometer writing arms (Model 398), and the marker arm (Model 401). The galvanometer writing arms are identified by the A-shaped frame attached to the top of the galvanometer. The small nichrome ribbon at the end of the frame, resting on the edge of the paper table, is the writing stylus. There are four adjustments associated with the galvanometer writing arms:

.... The clamping screw which sets the level of the arm and secures it to the galvanometer.
.... The pressure adjustment screw which sets the force of the stylus on the writing edge.
.... The stylus centering adjustment which sets the arm to mechanical center.
.... The writing arm limiters which restrict the travel of the arm to the recording chart.

These adjustments can be identified in Figure 3-2.

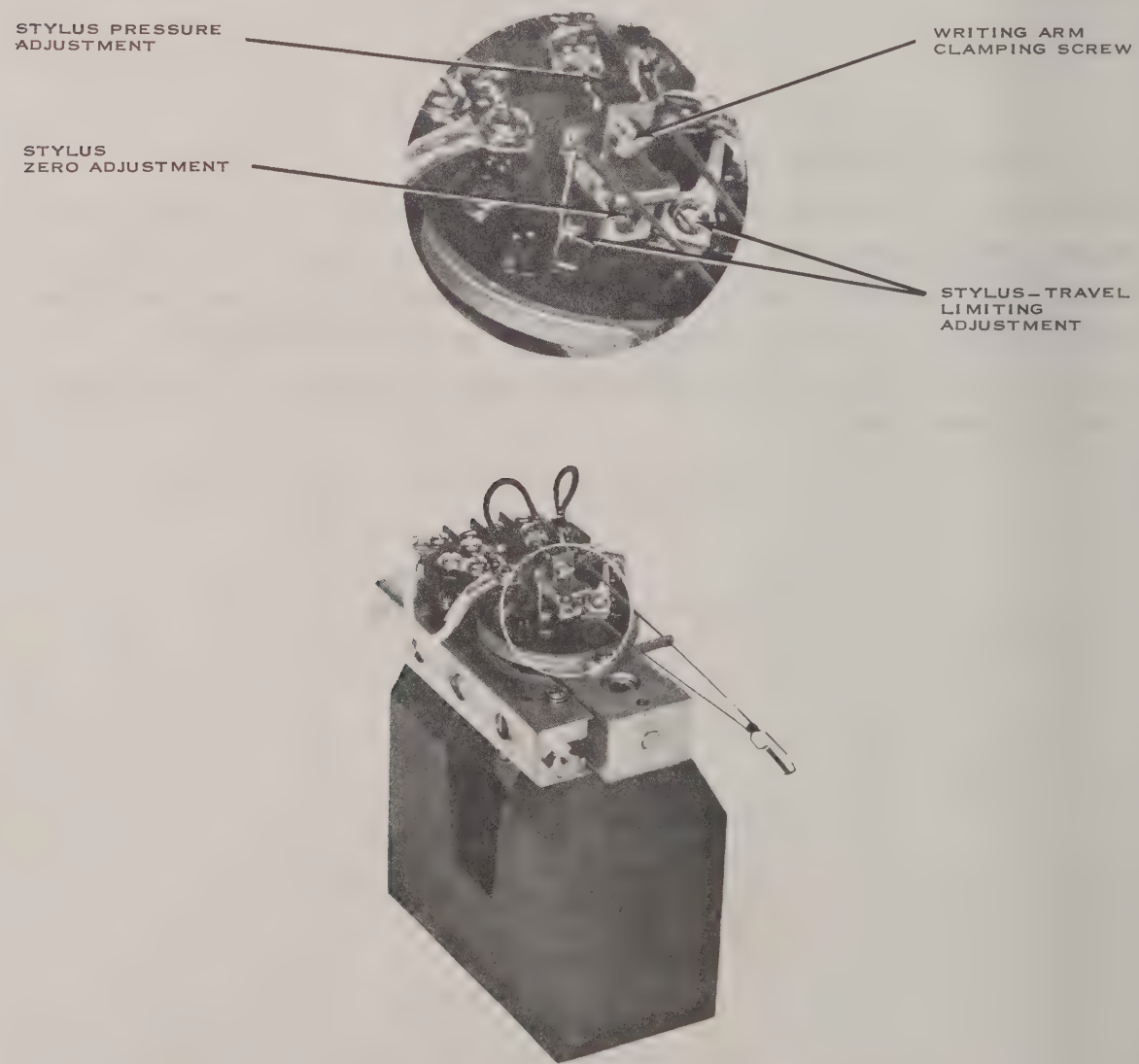


Figure 3-2. Writing Arm Adjustments

3—3. WRITING ARM MAINTENANCE (CONTINUED)

The need for writing arm maintenance may be indicated by a blurred or indistinct baseline. This will require one or more of the following adjustments.

a. STYLUS PRESSURE

Check the pressure of the stylus on the writing edge with the Stylus Pressure Tester Model 442, as shown in Figure 3-3. This scale is included as an accessory.

To calibrate the scale:

(1) Remove the 2 gram standard from the bottom of the scale and hang it on the scale hook; there is a hole in the standard for this purpose.

(2) Hold the Tester vertical so that the scale hangs free. Slide the index ring to position its top edge opposite the 2 gram mark of the scale.

(3) Remove the standard weight.

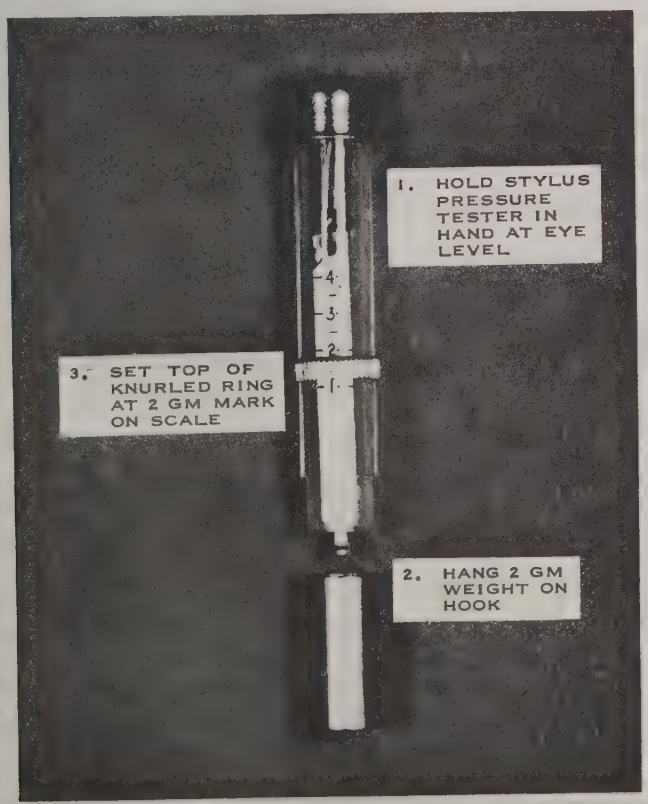

1. HOLD STYLUS PRESSURE TESTER IN HAND AT EYE LEVEL
3. SET TOP OF KNURLED RING AT 2 GM MARK ON SCALE
2. HANG 2 GM WEIGHT ON HOOK
4
3
2
1

Figure 3-3. Stylus Pressure Tester, Model 442

3—3. WRITING ARM MAINTENANCE (CONTINUED)

To adjust the pressure:

Turn off the recorder and lift open the transparent viewing window.

Place the scale hook under the section of the stiff-wire arm nearest the point where the stylus ribbon contacts the Permapaper

Lift the Tester perpendicular to the writing arm so that the scale does not rub against the inner wall of the tube; be sure the stylus is not stuck to the plastic coating of the paper. Read the stylus pressure indicated just as the stylus leaves the paper; it should measure 1.5 to 2 grams.

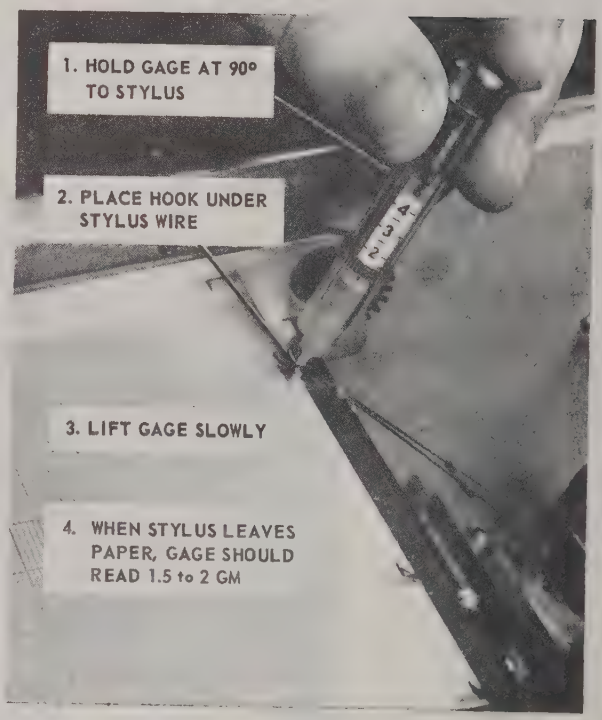

1. HOLD GAGE AT 90° TO STYLUS
2. PLACE HOOK UNDER STYLUS WIRE
3. LIFT GAGE SLOWLY
4. WHEN STYLUS LEAVES PAPER, GAGE SHOULD READ 1.5 to 2 GM

Figure 3-4. Writing Arm Pressure Test

Two holes are provided at the top of the case behind the galvanometers (one for each channel) to allow making adjustments on the stylus pressure adjustment screw. With a long, thin screwdriver inserted through the adjustment hole stylus pressure can be increased by loosening the adjusting screw or decreased by tightening the screw. After making an adjustment, recheck the pressure with the Pressure Tester.

b. STYLUS CLEANING

Accumulations of Permapaper coating on the stylus ribbon may prevent clear, well defined recordings. If the ribbon is only lightly coated, it can be burned away by increasing the stylus temperature.

(1) Push the writing table lock lever (at the top left edge of the paper table) toward the galvanometers, releasing the table and lifting the writing arms from the paper.

(2) Turn the paper drive on at its highest speed.

3—3. WRITING ARM MAINTENANCE (CONTINUED)

(3) Rotate the stylus HEAT control to its maximum clockwise setting and allow the recorder to run for a few moments. The increased temperature may be sufficient to burn off the coating. If the preceding steps do not provide a better trace remove the writing arm.

(4) Loosen, but do not remove, the writing arm clamping screw. (Figure 3-2.). Lift the arm free, taking care that the magnetic pull does not cause the screwdriver to damage the galvanometer.

(5) Examine the surface of the hot-wire stylus. If the stylus is dirty, clean it by scraping gently with a sharp blade or rub it carefully with fine sandpaper. Do not use steel wool or abrasives containing metal particles. If the ribbon is bent, straighten it with tweezers. Replace the writing arm, tighten the screw, and check the trace. Check the stylus force with the Stylus Pressure Tester.

(6) If the above adjustments do not provide a more clearly defined trace, remove and replace the writing arm with a new one.

(7) If the traces of both channels are blurred, check the Permapaper as it passes over the top of the writing edge. There should be no sign of looseness; the paper should be taut as it passes over the edge so that the stylus has as sharp and small a surface as possible on which to write. If necessary, adjust the paper brake for optimum paper tension. (See Paragraph 3-6).

c. MECHANICAL CENTERING

When the instrument is turned off, the stylus at the end of each writing arm should be centered in the middle of its ruled chart area, within ±1 millimeter. If adjustment is required, loosen the stylus zero adjustment screw (Figure 3-2) using the spline wrench included as an accessory. Move the writing arm to the correct position and tighten the screw.

d. MECHANICAL LIMITING

Each galvanometer is provided with two mechanical stops to prevent peak deflections from causing entanglement of the writing arms, or hooking of the arms on the ends of the writing table. To adjust the stops:

(1) Using a non-magnetic screwdriver, loosen the clamping screw of the galvanometer stop nearest the marker arm. Adjust this stop (slotted holes are provided) to limit writing arm excursion to between one and two millimeters beyond the ruled area for the chart.

3—3. WRITING ARM MAINTENANCE (CONTINUED)

(2) Adjust the remaining stop of this galvanometer and the stops of the other galvanometer to limit writing arm excursions to two millimeters beyond the ruled area of the chart.

(3) Turn on the recorder and rotate each POSITION control from one extreme to the other checking that writing arm travel is within these limits. If not, turn off the recorder and readjust the limiters.

e. MARKER ARM

The construction of the marker arm in the right margin of the chart is similar to the galvanometer writing arm. It is attached to a spring arm by a clamp and screw assembly on which is mounted a small coil. A low a-c voltage from the power supply excites the coil to produce line frequency vibrations of the arm.

Procedures described in step b can be used in cleaning this arm. To remove the arm for replacement, remove the two screws which clamp the heater leads to the terminal block and loosen the small clamping screw on the spring arm. After installing a new arm, be sure these screws are tight.

3—4. FREQUENCY COMPENSATION AND DAMPING ADJUSTMENTS

Each channel of the recorder is adjusted for optimum response at high frequencies with its COMPENSATION control (R61) and DAMPING control (R64). These are front panel screwdriver adjustments.

a. Connect a variable frequency audio oscillator to the recorder INPUT connector for the channel under adjustment. Set the frequency of the oscillator to 10 cycles and turn the recorder on.

b. Set the paper speed to 5 mm/second and adjust the stylus HEAT control for maximum heat.

c. Set the DAMPING and the COMPENSATION controls to the approximate centers of their ranges.

d. Adjust the level of the signal or the sensitivity of the channel for a 10 mm. peak-to-peak deflection, centered about the chart center line.

e. Raise the oscillator frequency to 125 cycles while keeping its amplitude constant. Now, adjust the COMPENSATION control to give a 7 mm. peak-to-peak deflection.

3—4. FREQUENCY COMPENSATION AND DAMPING ADJUSTMENTS (CONTINUED)

f. Reduce the oscillator frequency to 45 cycles and adjust the DAMPING control for a peak-to-peak deflection of approximately 9-1/2 mm.

g. Reduce the oscillator frequency to 10 cycles and adjust the signal level to obtain a 10 mm. deflection again.

These adjustments should provide the specified sine wave and transient response. To check the latter:

h. Rotate the RANGE switch to .5, position the writing arm to 10 mm. to the right of center with the POSITION control, and calibrate for 20 mm. across the center of the chart.

i. With paper speed at 20 mm./second and stylus heat adjusted for good definition, throw the lever from ZERO to CAL and back. The trace should rise smoothly to its final amplitude and should not overshoot more that 4% (0.8 mm) if at all. (See Figure 3—5.)

j. If the overshoot is excessive, adjust the DAMPING control to reduce it.

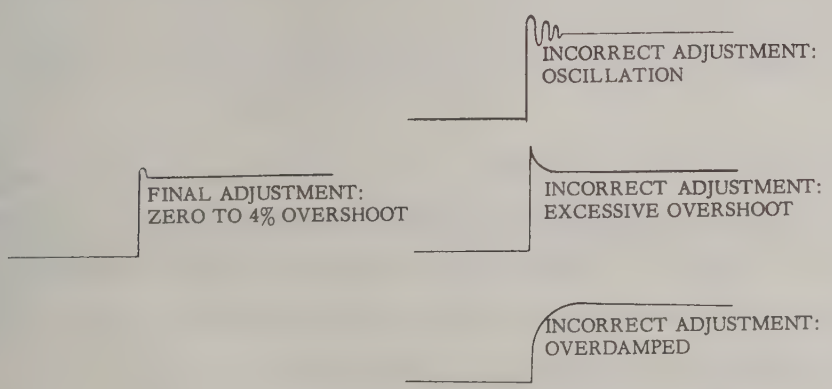


Figure 3-5. Damping Adjustment Wave Forms

3—5. PARALLAX CORRECTION

Parallax is present when the timing lines of the Permapaper are not parallel to the writing edge. It is important that the entire length of each timing line should cross the edge at the same instant.

To check for parallax:

a. Run off two or three feet of paper at the highest speed. Now, turn the chart drive off so that the paper remains taut over the writing edge.

3—5. PARALLAX CORRECTION (CONTINUED)

b. Mark the extreme left and right edge of the paper at the point where it crosses over the edge. Marking may be done by rubbing the surface of the Permapaper where it crosses the edge with a smooth straight object. Be careful that the mark is made with the marking tool crossing the edge at a constant angle; if the marking tool crosses at a variable angle, a false indication of parallax will result.

c. Run the paper a few millimeters to bring the marks into view. They should be on or equidistant within 0.25 millimeter from the same grid timing line at both extremes of the paper; if they are, the timing lines are parallel to the edge and no corrections are necessary.

d. If parallax does exist, it is caused by the writing edge and a paper supply roll which are not parallel. The first step to take to correct this condition is to try another roll of Permapaper, eliminating the possibility of incorrectly rolled paper.

e. If the preceding step does not correct the error, open the paper table and note the two eccentric stops above the paper spool. The paper table rests on these when closed. Close the paper table and examine it to be sure it is properly seated. Tap the paper table with a metal object evenly along a line parallel to, and one inch in front of, the writing edge. If the sound of the tapping changes from one side to the other, adjust the eccentric stop under the paper table where the tapping sound becomes louder or hollower.

   Lift the paper table and adjust the appropriate eccentric with a large screwdriver until a setting is found at which tapping sound indicates the paper table seats correctly; tighten the hexagonal nut holding the eccentric stop to secure the stop adjustment.

f. Examine the writing edge which clips over the edge of the writing table. If it is not flush with the edge of the table, press in at both ends.

3—6. PAPER TENSION AND TRACKING ADJUSTMENT

The paper drive is designed to track the Permapaper accurately within limits of ±0.25 millimeter. If the chart drifts to one side in its travel over the writing edge make the following checks.

a. When mistracking occurs immediately after inserting the Permapaper, the paper has probably been inserted into the drive at an angle, or has not been centered. This type of mistracking will correct itself in the first few feet of paper run through the drive. If mistracking is present to an excessive degree, roll the paper back and insert it into the drive again with more attention to the loading technique.

3—6. PAPER TENSION AND TRACKING ADJUSTMENT (CONTINUED)

b. Check to see that the paper is riding over the rear brake roller, under the front pressure roller, and is leaving the recorder freely from the front. If the paper is caught under or around either roller, an extra load is placed on the drive mechanism which accentuates any other problems of paper feed or tracking.

c. If the mistracking persists, remove the roll of Permapaper from the spindle and check the end faces of the roll with a straight edge to see if it is perfectly flat. Flatten it if necessary by tamping the convex end face.

d. If mistracking still occurs, or there is a tendency for the paper to tear as a result of too much tension, or the paper passes over the writing edge too loosely to obtain a distinct trace, the braking mechanism located inside the rubber brake roll must be adjusted. Adjustment is made by lifting the paper table and turning a screw at the right hand end of the brake roll. When the screw is brought out toward the end of the roll, the brake tension is decreased. When the screw is turned toward the center of the roll, the tension is increased. Ideal braking is obtained when the paper is tight as it passes over the writing edge.

The brake tension is set at time of manufacture and normally does not require further adjustment. However, when using translucent Permapaper, more tension is required. Readjust the brake when returning to regular paper.

3—7. CASE REMOVAL

To perform the adjustments described in the following paragraphs, it will be necessary to remove the recorder from its two-piece carrying case

a. Place the recorder in its vertical operating position.

b. Remove the four screws from the back of the case and the single screw on each side of the case.

c. Now, carefully lift the outer part of the case away from the inner part. The recorder is not secured to the inner half of the case; for removal, simply lift the recorder out and place on a work bench.

3—8. INSPECTION

a. Blow out both the chassis and the case with an air hose.

b. Clean the panel and the case with a cloth moistened lightly with alcohol or other mild cleaning solution. Wipe dry with a soft, clean cloth. Be careful not to scratch the panel finish.

c. Inspect the recorder for loose components, particularly plug-in components such as transistors, mounting boards, etc.

d. Check that all panel mounted components are securely in place. Check that all controls turn firmly and smoothly.

e. Inspect for damage, visually and by smell. Look for burned or worn insulation, leakage, damaged resistors, capacitors, etc. Inspect for rust, corrosion, etc.

f. Check the paper drive system. First remove the writing arms and the Permapaper. Clean the writing edge and viewing window with a cloth moistened with alcohol or other mild cleaning solution; do not use an abrasive. Inspect the writing arms; if the styli are dirty or misshapen, refer to Paragraph 3-3 for cleaning and adjustment.

3—9. CALIBRATION CELL REPLACEMENT

Calibration voltage is supplied by a 1.34 volt mercury cell for each channel. The life expectancy of these cells is approximately two years. If it should become impossible to obtain at least 20 millimeters of writing arm deflection when calibrating, remove and replace the cell of the affected channel.

a. Remove the amplifier plug-in board of the channel affected.

b. Remove the guard shield can from the CAL-ZERO-V/CM-MV/MM switch (S2).

c. Identify the cell which is soldered to terminal lugs which are fastened to the printed wiring board. Unsolder and install a fresh cell (Sanborn part number 2A-15A), then reassemble the recorder.

a. Lubrication Interval and Materials.

The paper take-up requires lubrication every six months or 1000 operating hours, whichever comes first. At this time, the paper take-up motor, gear train, and spindle assembly should be lubricated with the following materials:

MATERIAL	HEWLETT-PACKARD PART NUMBER	USED ON
Gear Train Grease	6040-0222	Drive gears, friction cork disc of spindle.
Machine oil (SAE#10)	6040-0220	Drive motor, oilite bearings of spindle

The paper take-up motor and drive gears can be lubricated in place, but the spindle assembly must be disassembled for lubrication.

b. Lubricating the Motor and Drive Gears.

Remove the paper take-up from the recorder or from the mounting rack, and lubricate the motor and drive gears as follows:

(1) Apply 7 or 8 drops of machine oil to the bearing felts at either end of the gear box and at either end of the motor shaft.

(2) Apply gear train grease evenly and sparingly to the gear teeth while rotating the assembly by hand.

c. Lubricating the Spindle Assembly.

The paper take-up is driven by an endless belt from its own motor and gear train. The drive pulley, endless belt, and pressure discs act as a slip clutch that keeps the tension constant across the take-up spindle when the cork friction discs are properly lubricated.

d. DISASSEMBLING THE PAPER TAKE-UP FOR LUBRICATION. If the take-up is performing badly or if lubrication is required, disassemble the clutch assembly as follows:

(1) Remove paper take-up spindle by releasing spindle at right side in a down and outward pull.

(2) Remove adjusting knob, lock screw and spring from the left end of the clutch assembly.

(3) Slip the drive belt off the clutch pulley.

(4) Carefully remove the pulley and friction clutch assembly from the shaft and bearing assembly. The shaft need not be removed from the bearing.

e. CLEANING AND LUBRICATING PARTS. Wash all take-up parts with a grease solvent such as chlorothene. The pulley groove may need brush cleaning to remove foreign matter. When parts are thoroughly dry, lubricate as follows:

(1) Apply gear train grease evenly and sparingly to the inner face (pulley side) of each cork disc.

(2) Oil the spindle bearings (3 points) with machine oil.

(3) Lightly coat the end of the take-up shaft (in the area of the tension spring) with gear train grease.

3—11. ASSEMBLING THE PAPER TAKE—UP SPINDLE.

Reassemble the pulley and clutch assembly using the following procedure:

NOTE: The tension spring must be oriented with the turned-in end facing the take-up locking knob. This end of the spring slides in the slot in the pulley shaft. The spring is compressed and released by the adjusting screw for paper tension.

(1) Install pulley and clustch assembly onto the shaft. Be sure the greased faces of the cork tension discs face inward to the pulley.

(2) Slip the endless belt onto the pulley.

(3) Install paper take-up adjustment spring cap and screw to hold pulley and clutch assembly in place.

(4) Install hexagonal paper core (if used) onto spindle.

(5) Align and install spindle first onto spindle insert at end of pulley shaft, and then slip it into the bracket at the right side of the pivot arm. The take-up is now lubricated and reassembled. Adjust paper tension per trouble-shooting procedure (see paragraph 3-15, Item No. 1) Paper Too Loose or Tight on Spindle.

3—12. SUPPLY VOLTAGE ADJUSTMENT

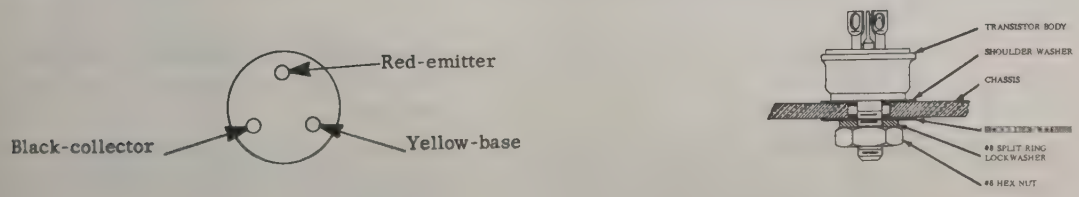
The regulated supply voltages, + and -12 volts d-c, are set with potentiometer R68. This control is located on the power supply plug-in board. Early Model 320 Recorders use plug-in board assembly Model 320-100-C12; later Model 320 Recorders use plug-in board assembly Model 320-100-C24.

a. To adjust regulated supply voltages using Model 320-100-C12 boards:
   (1) Identify screwdriver adjusted potentiometer R68.
   (2) Connect a d-c voltmeter of at least 10,000 ohms-per-volt resistance between chassis ground and the jumper wire adjacent to the board connector.
   (3) Adjust R68 for exactly -12 volts ±0.2 volt.

b. To adjust regulated supply voltages using Model 320-100-C24 boards:
   (1) Identify screwdriver adjusted potentiometer R68.
   (2) Connect the test meter between the test point at the end of resistor R69 (labeled ←12V) and chassis ground.
   (3) Adjust R68 for exactly +12 volts ±0.2 volt.

3—13. TRANSISTOR REPLACEMENT

Transistors used in this instrument are reliable under normal operating conditions. Excessive heat is the most common cause of failure, and in the case of power transistors, is sometimes caused by loose mounting screws. Transistor replacement requires a few precautions. For socket mounted types, be careful that the replacement transistor has its pins properly aligned with its socket holes. Do not force it into the socket; it should go in easily. Also, when replacing two or more transistors simultaneously, be sure to install the transistors in the proper sockets. Replacement of larger transistors, requiring unsoldering of leads, is more critical. Do not allow the soldering iron to overheat the transistor; use a pair of long-nose pliers to grasp the leads and to act as a heat sink. Be sure to mount the replacement transistor securely to the heat sink. Transistor Q13 (2N158) is supplied with color coded leads as shown in Figure 16a. Emitter, base, and collector terminals of output transistors Q18 and Q19 (H5G1) are identified by the letters e, b, and c. Reassemble this transistor as shown in Figure 3-6.



a. b.

Figure 3-6. Transistor Assembly

3—14. TROUBLE SHOOTING HINTS

Using an ohmeter:

When checking for open circuits on any of the amplifier assemblies, be sure to remove the transistors associated with that circuit before making the check. If possible, remove the entire printed wire assembly if it is of the plug-in type. Never use an ohmeter to check transistors as the voltage applied may "punch through" and consequently permanently damage the transistors. When making checks of precision resistors, use a good electronic meter of 3% full scale accuracy.

Single-Channel Defects:

Single-channel defects are readily isolated by the substitution method. Since both channels use identical plug-in components (i.e. transistors, batteries, etc.) simply interchange components from the channel which is working to the faulty channel.

Transistors: All transistors may be interchanged from channel to channel. Q10 - Q11, Q14 - Q17 (matched pairs) and Q1 - Q12 may only be replaced with their counter-parts in the working channel. Before changing transistors, be sure to turn the recorder off.

Batteries: Calibration batteries are the same for both channels. If both batteries are suspected to be faulty, replace with fresh batteries.

Galvanometer: To check a suspected galvanometer, simply interchange galvanometer leads on the terminal block at the top of the galvanometer. Be sure to note the color code of the leads.

Checking voltages: When making voltage checks on any part of the amplifiers, use a voltmeter of at least 10,000 ohms-per-volt resistance. To set the + and - supply voltages (12 volt), refer to Paragraph 3-12.

Stylus Heat: Insufficient stylus heat may be caused by any one of the following factors:

Carbon deposit from the slider arm of the stylus heat potentiometer.	Carefully clean the wire surface with non-toxic cleaning fluid.
Poor contact at the writing arm clamp.	Remove the writing arm, clean the contact surface and re-clamp securely.
Open stylus ribbon.	Replace with new writing arm.
Loose heater leads at galvanometer mounting block.	Tighten all terminal screws securely.

3—15. INSTRUCTIONS FOR TROUBLESHOOTING

Use the procedures in table below for troubleshooting the paper take-up.

TROUBLE	REMEDY
1. Paper too loose or tight on Spindle	Perform the following procedure: 1. Run recorder at 25mm/sec for preliminary check of paper tension between drive roll and take-up spindle. Tension should be snug, but not tight or loose. Turn clutch spring cap counterclockwise to loosen. Adjust clutch adjustment screw clockwise and counterclockwise until finger pressure depresses paper slightly.
	2. Run recorder at highest speed setting and make clockwise and counterclockwise adjustments until paper tension is correct.
	3. Repeat adjustments at slow speeds, then check operation at high, medium and low speeds to check overall operation of paper take-up. NOTE The paper take-up may operate erratically at slow speeds if the clutch is not fastened tightly. Tighten the clutch spring cap to lock (clockwise) after each and final adjustment.
2. Unit chatters at Speeds less than 5mm/second	First check that cork friction discs of paper take-up clutch are properly lubricated with gear train grease (see paragraph 3-10). Chattering of the paper can also occur if the similar friction discs of the paper brake roll in the recorder need lubrication.

3—15. INSTRUCTIONS FOR TROUBLESHOOTING (Continued)

TROUBLE	REMEDY
3. Paper Does Not Roll Up Evenly	Check installation of recorder and paper take-up to see that take-up roll is exactly parallel to recorder paper rolls. Check for bent pivot arm frame.
4. Paper Over-rides Paper Take-Up.	Motor is running slower than recorder drive motor. Check that paper take-up motor is rated for line frequency used; condition would occur if 60-cycle motor is used on 50-cycle line.
5. Motor Strains, Overheats, Slips Clutch at Excessive Rate, Draws Excessive Current.	Motor is running faster than recorder drive motor. Check that paper take-up motor is rated for line frequency used; condition would occur if 50-cycle motor is used with 60-cycle line or if either 50 or 60 cycle motor is used with 400-cycle line voltage.
6. Pilot Light Lights but Take-Up Does not Rotate.	Turn power switch off and check for following conditions: 1. Jammed gear box or stripped gear. 2. Endless belt broken. 3. Seized bearing in motor, gearbox or spindle assembly. 4. Burned or disconnected wire in motor circuit. 5. Blown fuse. Use fuse rated 1.25-A Slow-Blow. 6. Insufficient tension on clutch friction discs. See Trouble No. 1.
7. Take-Up Rotates but Pilot Light Does not Light.	Defective lamp, socket or associated wiring.

3—16. PRECAUTIONS TO BE OBSERVED WHEN USING PAPER TAKE—UP

a. Description of Hazards to Personnel.

If normal precautions observed in handling and servicing electrical and mechanical equipment are followed, there are no significant hazards to personnel operating the paper take-up.

b. Description of Hazards to Equipment.

When the 320-series recorder is to be operated unattended or in a remote location, the paper take-up should be used. Otherwise, it is possible for the paper to wrap around the drive roll, build up in thickness, and cause the recorder gear box to be damaged.

3– 17 PRINTED WIRING BOARD TECHNIQUES

The following procedures will help in making fast, trouble-free removal or replacement of components.

a. Remove the screws which hold each printed wire board to the recorder chassis, then pull the board from its connector, taking care not to damage the components.

b. For amplifier boards, remove the screws holding the shields to the boards.

c. Use as little heat in soldering as possible. A 25 watt soldering iron with a small pointed tip is recommended. Touch the tip of the iron to the lead of the part to be removed, not to the printed board itself. Apply heat to the soldered side of the board - not to the component side.

d. When removing a component, or when tinning a lead, hold the lead itself, next to the body of the resistor, condenser, etc., with pliers, as a heat sink to prevent overheating of the component.

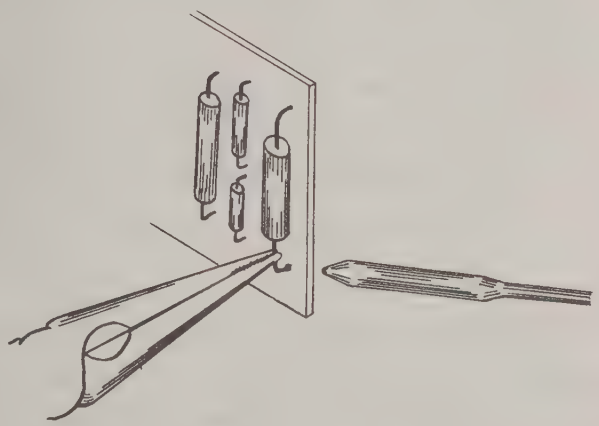


Figure 3-7. Component Removal Technique

e. Carefully clean and tin the leads of the replacement part. Hold the lead with pliers as described in step d.

f. Now insert the new part in place through the holes in the printed wire board, with the replacement component held against the board. Carefully solder in place with a minimum of heat, using a pair of long nose pliers as a heat sink adjacent to the replacement part.

g. Replace the shields on the amplifier boards. Carefully insert the printed wire board into its connector; do not bend or use force. Replace the mounting screws removed in step a.

SECTION 4

CIRCUIT THEORY

4—1. INTRODUCTION

Each channel of this instrument contains a sensitive and stable recording carrier amplifier. A 1200 cycle transistor modulator in the input circuit reverses the polarity of the input signal 2400 times per second. The resulting output signal is a 1200 cycle amplitude-modulated square-wave. The height of this square-wave is proportional to the amplitude of the input signal; the phase of the square-wave (0^{o} or 180^{o}), with respect to the excitation signal of the modulator, represents the polarity of the input signal. Conversion of the input signal (which may be d-c or low frequency a-c) to a 1200 cycle square-wave allows the signal to be amplified by an a-c amplifier, avoiding the baseline drift which might otherwise occur in a d-c amplifier of the same sensitivity.

4—2. GENERAL

This section of the instruction manual is used in conjunction with the schematic and block diagrams found at the rear of the manual. Note that the schematic diagram divides naturally into sections, determined for the most part by printed wiring boards. Only one channel of the instrument is represented on this diagram.

. . . In the lower left-hand corner of the diagram you will find the circuit details of the input and modulator section on assembly 320-100-C30.

. . . To the right of the input circuit may be found the RANGE (attenuator) switch circuit details on assembly 320-100-C3.

. . . At the far right of the diagram is the power supply, oscillator and voltage regulator circuits. This printed wiring plug-in board is common to both channels and is identified as assembly 320-100-C24.

4—2. GENERAL (CONTINUED)

. . . At the top of the diagram, running from left to right, is the heart of the recorder, containing the a-c amplifier, demodulator, and driver amplifier sections. This is a plug-in printed wiring board and is identified as assembly 950-3400.

. . . In the right center of the diagram you will find the circuits for the stylus heat, push-button control, amplifier power output stage, galvanometer and marker, paper drive and timing motor, and power supply circuits.

4—3. COMMON—MODE (IN—PHASE) SIGNALS

Before discussing circuit theory of the amplifier, it is important to describe the signals which may be applied, and show what happens to them.

Assume an amplifier which has two input terminals. Call one terminal "A" and the other terminal "B". The amplifier ideally responds to the voltage between "A" and "B". This voltage between "A" and "B" is the "differential voltage".

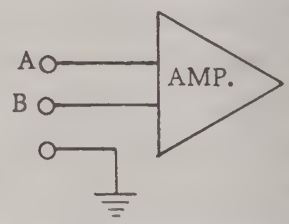


Figure 4-1. Differential Amplifier

Mathematically, the differential voltage can be expressed as B - A or as A - B. So if terminal "A" is at +1.3 volts, and terminal "B" is at -1.3 volts, this amplifier will respond to the 2.6 volts differential voltage. But now assume that terminal "A" is at +3 volts, and terminal "B" is also at +3 volts. Obviously, the differential voltage is zero. The question is: will the +3 volts at both "A" and "B" interfere with the proper operation of the amplifier? This +3 volts is a "common-mode" or "in-phase" component, because it appears at both input terminals with the same voltage and the same polarity at the same time. Mathematically, the common-mode (or in-phase) component =

$$\frac{(\text{volts at "A"}) + (\text{volts at "B"})}{2}$$

Since the amplifier is intended for differential measurements only, it should ignore this common-mode voltage completely. But no electronic amplifier is perfect, and the common-mode voltage may have some slight effect. The characteristic known as "common-mode rejection" is the figure which shows how perfectly the common-mode component is kept from affecting the amplifier.

4—3. COMMON—MODE (IN—PHASE) SIGNALS (CONTINUED)

Practical examples of common-mode voltages are: capacitive pickup on input signal cables; a signal circuit which is elevated above or below ground potential because of ground loops; a signal source which inherently includes a common-mode component because of its circuit design, etc.

This amplifier achieves a high common-mode rejection ratio because of its input circuit design. In this amplifier, the input signal is applied to a transformer through a modulator which expresses the input signal as a 1200-cycle square-wave. Any common-mode component is (ideally) applied equally to both terminals of the transformer; as a result, no common-mode component is applied across the primary so as to induce a common-mode component at the secondary. In addition, a dual shield between the primary and secondary of the transformer prevents capacitive coupling of common-mode signal components, between the primary and secondary of the transformer.

These circuit procedures for rejecting common-mode signal components are effective only as long as a portion of the common-mode does not become transformed in some way into a differential signal; if this happens, then the amplifier is unable to discriminate against this differential component, but will amplify it along with any of the other differential signals which the amplifier is designed to accept.

The cause and cure for this problem is discussed in the following paragraph.

4—4. GUARD SHIELD THEORY

The preceding paragraph showed that the amplifier will reject common-mode signals except for any part of the common-mode signal which may become transformed into a differential signal before it reaches the amplifier input terminals. This paragraph shows how a part of the common-mode signal can be changed into a differential signal, and what to do to prevent it.

Assume a signal source connected to the amplifier as in Figure 4-2.

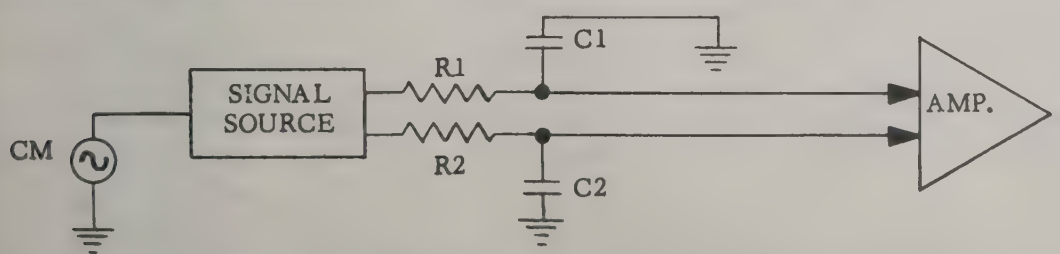


Figure 4-2. Method of Changing Mode Signal Into a Differential Signal

4—4. GUARD SHIELD THEORY (CONTINUED)

With this circuit, CM is the common-mode signal, R1 and R2 are the series resistances of the two sides of the signal source and the cabling (the general case would use Z1 and Z2 as the two source impedances), and C1 and C2 are the cable and stray capacitances of the two sides of the signal source and cabling.

In the upper lead, R1 and C2 form a low pass filter, so that (when CM is an a-c signal) only a portion of CM appears at the upper terminal of the amplifier. Similarly, R2 and C2 form another low pass filter, so that only a portion of CM appears at the lower terminal of the amplifier. These portions may be large or small.

Now, if the two sides of the circuit are perfectly balanced (R1 = R2, C1 = C2) then the portion of CM which appears at the upper terminal is exactly the same as the portion of CM which appears at the lower terminal: the common-mode signal remains a pure common-mode signal, which the amplifier is designed to reject.

However, if the two sides of the circuit are not perfectly balanced, then the portion of CM which appears at the upper terminal is no longer exactly the same as the portion of CM which appears at the lower terminal; we have transformed a part of the common-mode signal into a differential signal, which the amplifier will not reject, but will treat as any other differential signal. This spoils the apparent common-mode rejection ratio. The same effect occurs with d-c signals, where the unbalance lies in R1 and any leakage resistance in parallel with C1, compared with R1 and the leakage resistance across C2.

What is needed here is a method of keeping an unbalanced signal source from transforming a portion of the common-mode voltage into a differential voltage. This is done with a guard shield.

The guard shield circuit uses two shields: an inner shield, connected to the common-mode voltage, and an outer shield, connected to the amplifier ground, as shown in Figure 4-3.

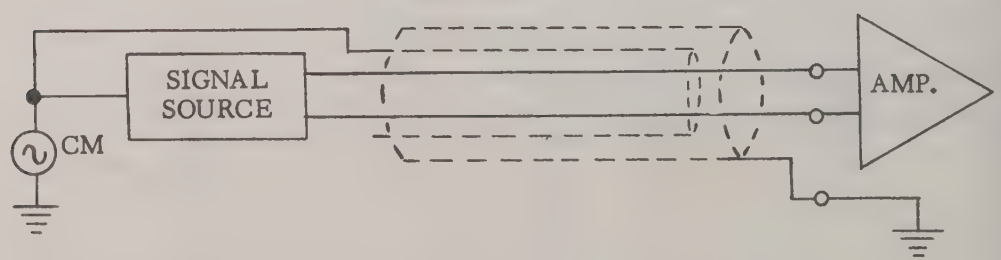
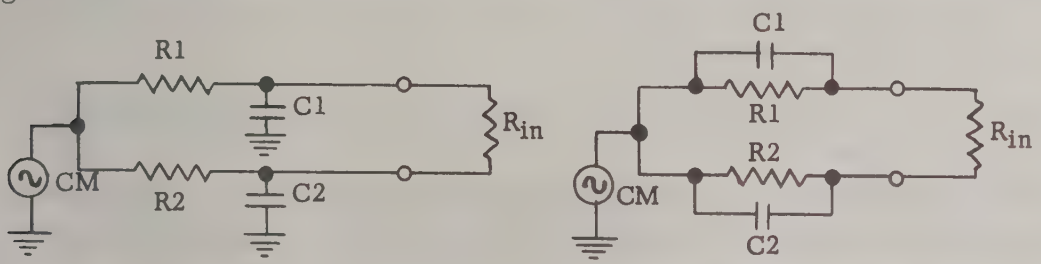


Figure 4-3. Guard Shield Circuit

4—4. GUARD SHIELD THEORY (CONTINUED)

With this inner shield connected, no current will flow through the stray capacitances and cable capacitances because both sides of the capacitances are at the same common-mode potential.

The equivalent circuits showing the resistances and the capacitances are shown in Figure 4-4.



Without guard shield: resistance and capacitance unbalance cause a differential voltage to appear across amplifier input R_{in}.

With guard shield: resistance and capacitance unbalance can no longer cause a differential voltage to appear across amplifier input R_{in}.

Figure 4-4. Equivalent Circuits

4—5. INPUT

The input circuit of this amplifier includes a four-position function switch (CAL-ZERO-V/CM-MV/MM) and a transistor modulator consisting of Q14, Q15, Q16, Q17 and transformer T2.

The function switch operates as a balanced attenuator, offering two primary ranges of sensitivity. Signals applied to the switch through terminal E of the front panel INPUT connector J1 are fed to the emitters of Q16 and Q17 of the modulator; signals applied to terminal F of J1 are fed to the emitters of Q14 and Q15.

The modulator transistors are driven by the excitation voltage supplied by the oscillator circuit, and coupled to the bases of the transistors through transformer T2. The modulator reverses the polarity of the input signal 2400 times per second. The resulting output is a 1200-cycle square-wave signal applied to the input transformer T3 which couples the signal to the first stage a-c amplifier.

In the CAL position, the emitters of Q16 and Q17 are removed from the input signal and instead connect to a 10 millivolt d-c calibration voltage derived from calibration cell BT-1 and resistors R47, R48 for amplifier gain adjustments.

The ZERO position of the function switch ties the emitters of the modulator transistors together so that a reference or baseline may be established with the POSITION control.

4—6. INPUT AMPLIFIER

The two-stage input amplifier consists of transistors Q1 and Q2 and associated components. The input signal is applied to the base of Q1; the output signal from the collector of Q1 is direct-coupled to the base of Q2. A negative voltage feedback loop between the collector of Q2 and the emitter of Q1 stabilizes the a-c gain of the circuit. Blocking capacitors C3-C6 prevent changes in feedback from disturbing d-c voltage conditions of the two stages.

4—7. GAIN AND RANGE CONTROLS

The GAIN (sensitivity) and RANGE (attenuator) control circuits are physically located on the front panel of the recorder.

a. The GAIN control is effective for all positions of the RANGE switch. Moving this control changes the amount of signal voltage fed from the output of Q2 to the input of Q3.

b. The RANGE switch is divided into two circuits. In the .5, 1, and 2 positions, the change in overall gain required for attenuation is provided by varying the amount of feedback in the loop between Q2 and Q1. In the 5, 10, and 20 positions, the change in overall gain required for attenuation is provided by varying the amount of feedback in the loop between the collector of Q5 and the base of Q3.

4—8. THREE—STAGE AMPLIFIER

The three-stage amplifier section Q3, Q4, and Q5 amplifies the signal from the input amplifier Q1-Q2 and drives the demodulator transformer T1. This direct-coupled transistor amplifier includes the following special features:

a. The input signal to Q3 includes two components; the (nominally) square-wave component from Q2, and the sine-wave component from the POSITION control R60. Note that either component may be at 0° or 180° phase relation to the a-c voltage from the reference source; the phase relation is interpreted by later circuits to provide an up-scale or down-scale deflection by the galvanometer writing arm.

b. The amplifier includes a d-c negative voltage feedback loop which is connected from the emitter of Q5 back to the emitter of Q3. The function of this loop is to stabilize the d-c operating voltages of this section of the amplifier.

c. The amplifier also includes an a-c feedback loop which is connected from the collector of Q5 back to the base of Q3. The function of this loop is to stabilize the signal gain of the amplifier against changes in component characteristics, supply voltages, etc.

4—9. POSITION CONTROL

The POSITION control is physically located on the front panel of the recorder. Electrically it is located across the ten-volt a-c reference line which also drives the modulator transistors. The voltage from this potentiometer is zero near the mid-point of the control, rises to a maximum at one extreme of the control, and to a similar maximum but 180° removed, at the other extreme. This voltage adds to the signal voltage applied to Q3 to give an output component from the demodulator for positioning the galvanometer writing arms.

4—10. DEMODULATOR AND FILTER

The demodulator, which includes transistors Q6 and Q7, center-tapped transformer T1, and the input capacitor of the filter, is a full-wave, phase-sensitive, synchronous peak detector. Circuit operation is shown in Figure 4-5

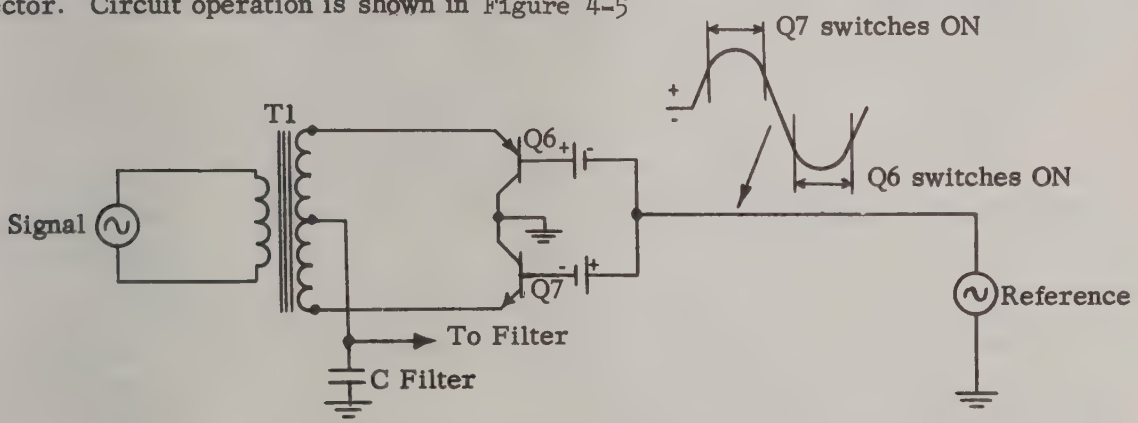


Figure 4-5. Basic Demodulator Circuit

With no signal or reference applied, transistors Q6 and Q7 remain off and appear as a pair of open switches because of the reverse bias applied to each transistor. (The bias is shown here as a battery; the actual biasing voltage is taken from the positive and negative regulated supplies through a resistance network).

With a reference only applied, Q6 and Q7 turn on and off alternately, and approximate a pair of perfect switches which open and close in synchronism with the reference voltage. The "ON" period occurs about the peak of the positive (Q7) and negative (Q6) reference voltage waveform. An essentially perfect switching characteristic is obtained because (1) the voltage interval between transistor-OFF and transistor-ON corresponds to a small time interval, and because (2) the emitter-collector circuit being switched has an extremely high "OFF" impedance (provided by the reverse bias) and an extremely low "ON" impedance (because of the common-collector transistor circuit).

4—10. DEMODULATOR AND FILTER (CONTINUED)

If a signal is now applied to the demodulator, in-phase or 180° out-of-phase with the reference, then one transistor or the other will contribute the larger amount of output. This results in a net d-c output, plus ripple components, where the d-c component has an amplitude proportional to the amplitude of the signal, and a polarity which represents the phasing between signal and reference. If, on the other hand, the signal should be at a time quadrature with the reference, then the two transistors contribute equally to the output, resulting in ripple components only, with no net d-c output. If an in-phase and a quadrature signal are present at the same time, the demodulator will respond to the in-phase component and almost completely ignore the quadrature component.

The filter which follows the demodualtor is a conventional low-pass R-C filter with output to the limiter circuit, front panel MONITOR OUTPUT jack and to the input of the driver amplifier (Q10).

4—11. LIMITER

Output signals from the demodulator are fed to the MONITOR OUTPUT jack and to the limiter stage. The MONITOR OUTPUT jack provides a convenient means for observing the signal waveform on an oscilloscope. The source resistance at this point is 10,000 ohms. A load resistance of 1 megohm will change the calibration of the recorder by 1%. Lower load resistances will require recalibration. Approximately 40 millivolts/millimeter of deflection is available.

The limiter consists of transistors Q8, Q9 and associated components. The transistors are connected in a complementary circuit, with the input signal supplied to the emitters, the collectors grounded and the operating bias on the bases taken from the regulated + and -12 volt supplies through a resistance network. The bias voltage acts as a reference against which the signal voltage is compared. When the level of the input signal exceeds the reference voltage, in either a positive or negative direction, the appropriate transistor effectively becomes a low resistance and clamps the signal at the level set by the reference voltage. This reference voltage is selected to limit writing arm excursions to approximately 115% of full scale.

4—12. DUAL AMPLIFIER

The signal from the limiter is fed to the dual amplifier which includes transistors Q10, Q11 and associated components. Transistors Q10 and Q11 may be considered as one stage having two inputs and a single output.

4—12. DUAL AMPLIFIER (CONTINUED)

a. The first input signal originates as the output from the limiter; this signal is applied to emitter-follower Q10. The output from this transistor is taken from the emitter and fed to Q11 as a signal input.

b. The second input originates as a feedback voltage from the galvanometer and includes both current and velocity feedback components.

The output signal is taken from the collector of Q11. This output includes three components of interest:

c. The signal, originally supplied to the base of Q10, which represents the input signal to the amplifier.

d. The current feedback signal, originating as the voltage developed across the series resistor R27 by the drive current through the signal winding of the galvanometer.

e. The velocity feedback component generated in the feedback winding of the galvanometer coil by its motion through the magnetic field.

Note that Q11 is a part of the overall feedback loop which includes the transistors which follow it in sequence of signal flow, and the entire electro-mechanical vibrating system of the galvanometer.

4—13. DC AMPLIFIER AND OUTPUT STAGE

DC amplifier Q12 and Q13 is a conventional two-stage transistor amplifier. Input (from Q11) is applied to the base of Q12. Output is taken from both the emitter and collector of Q13. These two outputs are of opposite phase and are of different amplitudes so as to properly drive the output stage Q18 and Q19 which follows.

The base of Q18 is driven from the collector of Q13, and the base of Q19 is driven from the emitter of Q13. Output from this amplifier (Q18-Q19) feeds the single-ended driving section of the galvanometer coil.

4—14. GALVANOMETER

The recording galvanometer used in this instrument is similar to the classic D'Arsonval movement, used in most d-c meters. However, it differs in several important particulars.

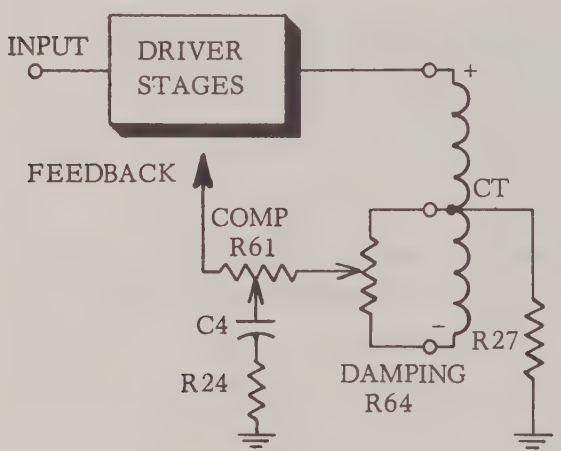
First, in order to operate at high writing speeds, an extremely stiff suspension is required to provide sufficient restoring force to the writing arm.

4—14. GALVANOMETER (CONTINUED)

Second, in order to generate the forces necessary to operate with such a stiff suspension, the coil is many times larger and heavier than comparable elements of a conventional moving coil meter.

Third, because it requires large forces to move the heavy coil, the magnetic structure is of tremendous size and strength by comparison with other D'Arsonval movements.

Finally, to provide the required galvanometer damping, the coil is constructed with two windings; an inside winding which carries the currents to drive the coil, and an outside winding which generates a feedback voltage which is returned to the driver amplifier for damping.



Note: the upper portion of the coil between + and CT carries the current which drives the coil into motion. The lower portion of the coil between CT and - generates a voltage proportional to the instantaneous velocity of the coil. (The a-c component induced by the transformer action of these coils may be ignored.)

Figure 4-6. Electrical Galvanometer Damping

Galvanometer damping may be achieved by two methods: mechanical or electrical. Analysis of mechanical damping shows that it is equivalent to applying a force to the coil which is proportional to the instantaneous velocity of the coil but in direct opposition to that velocity. A mechanical device could be designed to provide any degree of damping; however, it would be difficult to adjust and maintain.

Since mechanical damping is impractical, this galvanometer uses electrical means to damp coil motion. Electrical damping requires an electrical signal, proportional to the instantaneous velocity of the coil, which is applied to the amplifier so as to oppose the velocity. The velocity voltage generated by the coil is used for this purpose.

The galvanometer and the driver amplifier are included within one feedback loop. The feedback voltage contains two components:

a. Current feedback component, originating as the voltage developed across the series resistor R27 by the drive current through the signal winding of the galvanometer.

4—14. GALVANOMETER (CONTINUED)

b. Velocity feedback component, generated in the feedback winding of the galvanometer coil by its motion through the magnetic field. This voltage is proportional to the instantaneous velocity of the coil.

These feedback voltages are returned to the driver amplifier with such an electrical phasing as to oppose the signals which cause the galvanometer to move.

The function of the current feedback component is to keep the current through the signal winding of the coil independent of temperature changes in the galvanometer or drive circuit.

The function of the velocity feedback component is to allow galvanometer damping adjustments by electrical means. For best operation, galvanometer damping is adjusted to simulate 100% of critical. At this value the writing arm will reach its final stable value in a minimum of time in this circuit.

In this combination of driver amplifier and galvanometer, the DAMPING control R64, located in the feedback loop from the galvanometer, is adjusted so that the largest part of the damping is supplied by the signal generated in the velocity coil of the galvanometer. Both feedback components are adjusted by the COMPENSATION control R61 to complement the high frequency roll-off characteristics of the galvanometer. The latter adjustment serves to extend the response of the system beyond that of the galvanometer alone.

A smaller additional amount of damping is supplied by the coil frame of the galvanometer. This frame forms a complete closed-loop circuit, equivalent to a low-resistance, one-turn, short-circuited winding on the coil frame. The forces developed in this frame are proportional to the coil velocity, and are in such a direction as to reduce the coil velocity. This is exactly the relationship needed to damp coil motion.

4—15. POWER SUPPLY

The power supply consists of a transformer with a single low voltage, high current secondary winding, using a dual rectifier and filter network to provide output voltages which are equal in magnitude but of opposite polarity. These voltages are supplied to the driver and power output stages of the amplifier, and to the voltage regulating circuit which provides stable voltages to critical circuits in the amplifier.

4—16. VOLTAGE REGULATOR AND OSCILLATOR

Two separate voltage regulating circuits are mounted on plug-in board Model 320-100-C24. These are conventional series regulating circuits. In the positive supply, regulator transistor Q20 is in series with the current flowing through the load. Electrically, the regulator acts as a voltage dropping resistance because there is current flowing through it and a voltage drop across it. The effective resistance is controlled by changes in its base to emitter voltage. This is the basic principle of voltage regulation.

The regulator tries to keep the output voltage constant, independent of any change in the load current or of changes in the rectified d-c voltage from the rectifiers. A portion of the output voltage will appear at the base of control amplifier Q21 (the emitter of which is referenced by Zener diode CR11), and cause an amplified change of voltage to appear at its collector. Because the collector of Q21 is connected directly to the base of Q20, there will be a change in the base to emitter voltage of Q20 which changes the voltage drop across that transistor so as to oppose the original change in output voltage. Output from this circuit is adjusted to +12 volts by R68.

Operation of the negative regulated supply is similar with exception of the reference voltage for the control amplifier. This voltage is taken from the +12 volt supply. In this way, adjusting the +12 volt supply with potentiometer R68 simultaneously sets the -12 volt regulated supply.

Some instruments use a slightly different regulating circuit, however, operation is essentially the same. Potentiometer R68 is located in the negative regulating circuit and adjusting this control for -12 volts will simultaneously set the positive regulated supply to +12 volts. This regulator plug-in board is identified as assembly 320-100-C12. (See Paragraph 3-11, Maintenance Section).

A push-pull oscillator circuit, consisting of Q24, Q25 and associated components is also mounted on the regulator board. The operating frequency of this circuit is 1200 cycles. The output from the oscillator is supplied to the modulator, position control, and demodulator circuits.

4—17. TROUBLE SHOOTING HINTS

Trouble shooting procedures for the Model 320 are in most respects similar to those used on any electronic equipment. The technician will find that this instrument readily lends itself to the substitution method of locating defects due to the many plug-in assemblies and components which may be inter-changed from channel to channel. This is particularly helpful in locating defects which are confined to a single channel.

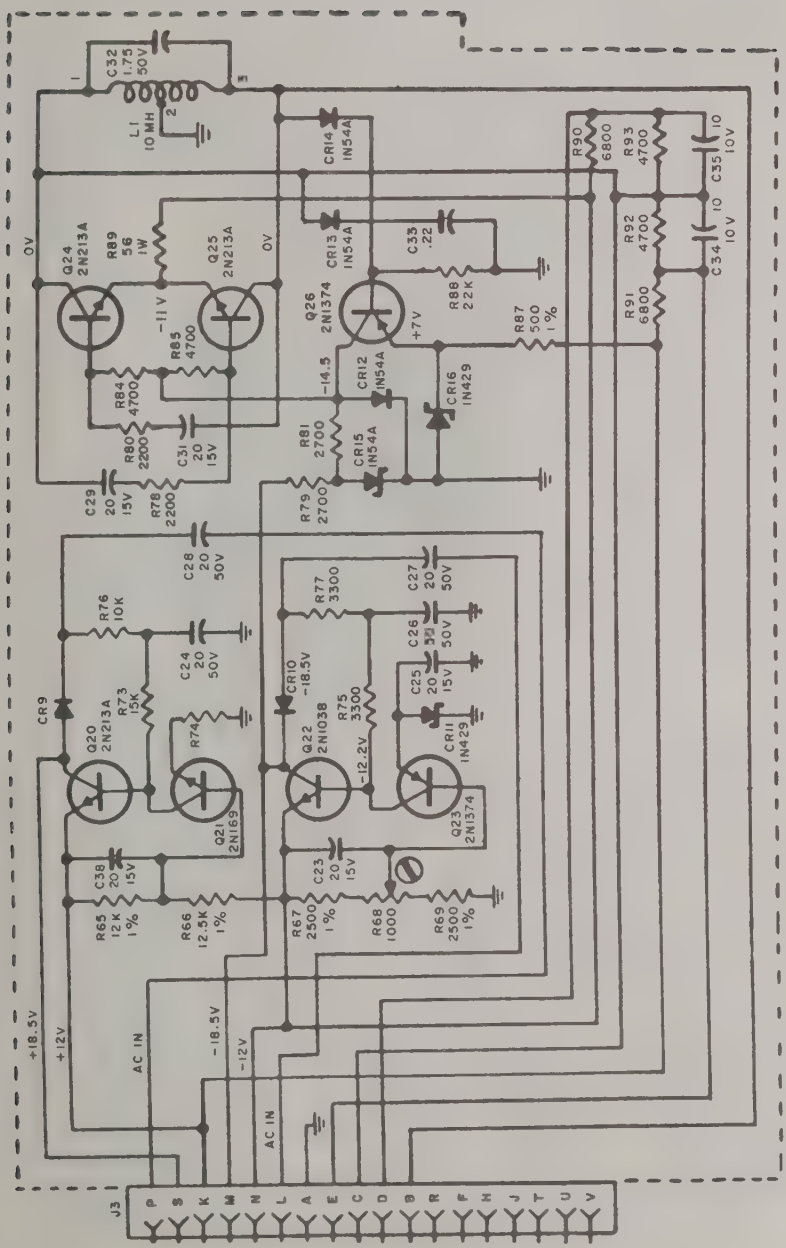


Figure 4-7. Regulator Card Assembly Model 320-100-C12.

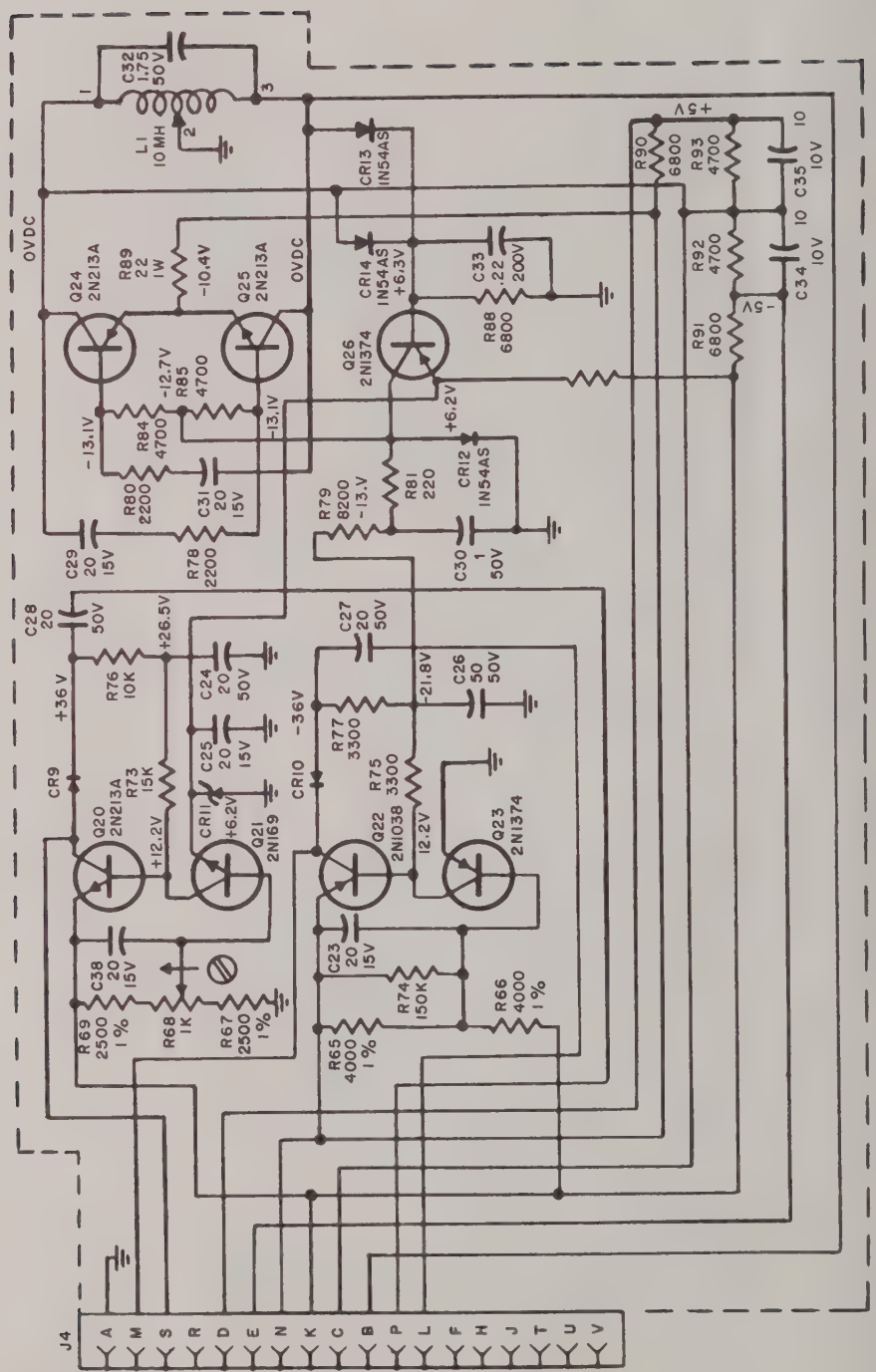


Figure 4-8. Regulator Card Assembly Model 320-100-C24.

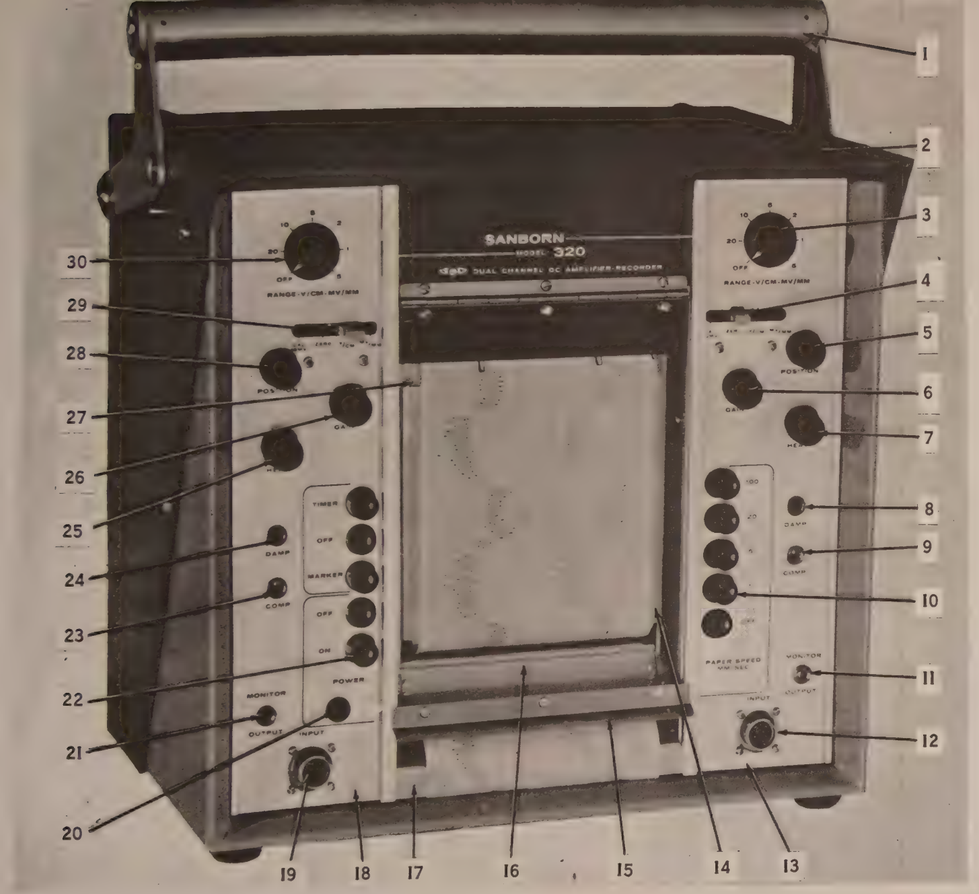


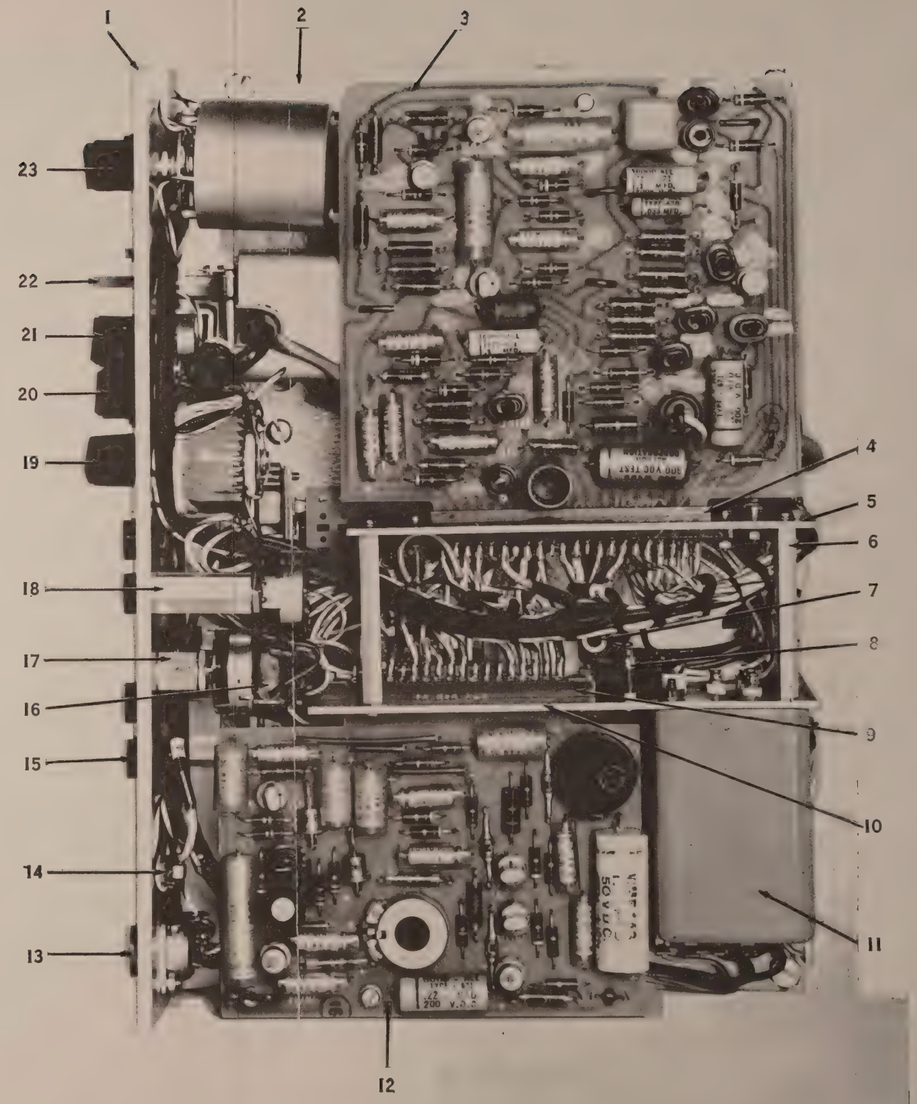
Figure 4-9.
Recorder model 320,
Front View

LEGEND

REF. NO.	DESCRIPTION
1	Handle Assembly (1) Handle (1) Brackets (2)
2	Carrying Case (1) Carrying Case (inside) (1) Carrying Case (outside)(1) Latch Screw (2) Interlock Washer (2) 10-32 Hex Nut (2) 3/8 x 24 Hex Nut (2) Retainer, Pin (2) Retainer, Spring (2) Pin, Handle Locking (2) Screw, Handle (2) Plug Buttons, 1/2" (2) Plug Buttons, 3/8" (1) Spring Coil (2) Washer (Handle mounting)(2) Washer (Handle mounting)(2) Rubber Feet (4) Rubber Feet (bottom) (4) 3/16 x 6-32 Screw (2) 1/2 x 6-32 Screw (4) 1/2 x 1/4-20 Screw (4) 1/2 x 8-32 Sems (8) 1/2 x 10-32 Sems (2)
3	7 Position Wafer Switch (SEE FIGURE 4-12)
4	Lever (S2B) Switch
5	Pot 250K (R60B)
6	Pot 15K (R52B)
7	Pot .5 Ohm (R71) 12.5 W
8	Pot 50 Ohm (R64B)
9	Pot 5K (R61B)
10	Switch, five button push button
11	Phone Jack (J3B)
12	3 Contact Male Connector
13	Panel, right control (1) Insert right front (1)
14	Table, paper drive assy. (SEE FIGURE 4-23)
15	Window Assembly Window, Recorder (1) Cover, Slide (1) Handle, Window (1) Spring, Window (1) Holder Latch Hinge, Window (1) Latch, Viewing Window (2) Spring, Viewing Plate (2)
16	Guide, Paper (1)
17	Shield Pressure Roll (1)
18	Panel, Left Control (1) Insert, Left Panel (1)
19	3 Contact Male Connector
20	Lamp Assembly (11) Power
21	Phone Jack (J3A)
22	5 Button Push Switch (S4)
23	Pot 5K (R61A)
24	Pot 50 Ohm (R64A)
25	Pot. .5 Ohm 12.5 W (R70)
26	Pot 15K (R52A)
27	Table Lock (1) Table Lock Spring (1)
28	Pot 250K (R60A)
29	Switch Lever (S2A)
30	7 Position Wafer Switch (S1A) (SEE FIGURE 4-12)

Figure 4-10.
Recorder Model 320,
Right Side View

REF. NO.	DESCRIPTION
1	Panel, Right Control
2	Side Plate, Right
3	Printed Circuit Board Assy See Figure 21
4	22 Pin Printed Circuit Conn.
5	Chassis, Upper Right 3/8 x 4-40 Sems Pem #4 Eyelet
6	Spacer, Hex (4) 3/8 x 6-32 Sems
7	Res. .25 Ohm 10 W Deleted
8	Insulated Standoff (3) 1/4 x 4-40 Sems
9	18 Pin Printed Cir. Conn. (J4)
10	Chassis, Lower Right
11	Transformer (T5) 6-32 Lockwasher 6-32 Hex Nut Lug, Right Angle
12	Printed Circuit Board Assy. See figure 22
13	3 Pin Male Conn. (J1B) 3/8 x 4-40 Screw Lockwasher #4 Hex Nut #4 Nylon Washer #4 Lug, Right Angle
14	Phone Jack (J3B)
15	Switch, 5 Button Push (S3) Bracket (1) Knob
16	Capacitor .047, 200V (C36B)
17	Pot 5K (R61B) Comp Pot Standoff Bushing Lug Pot
18	Pot 50 Ohm (R64B) Pot Standoff Bushing
19	Pot .5 Ohm, 25 W (R71) Lug, Pot Knob 1/4 Shaft
20	Pot 15K (R52B) Gain Lug Pot Knob 1/4 Shaft
21	Pot 250K (R60B) Position Knob 1/8 Shaft Lug 1/4 Hole
22	Rt. Cal. Assy. See Fig. 5 Knob, Switch Lever Washer, Nylon #4 3/8 x 4-40 Screw (SEE FIGURE 4-31)
23	SWITCH ASSY. (S1B) (SEE FIGURE 4-12)



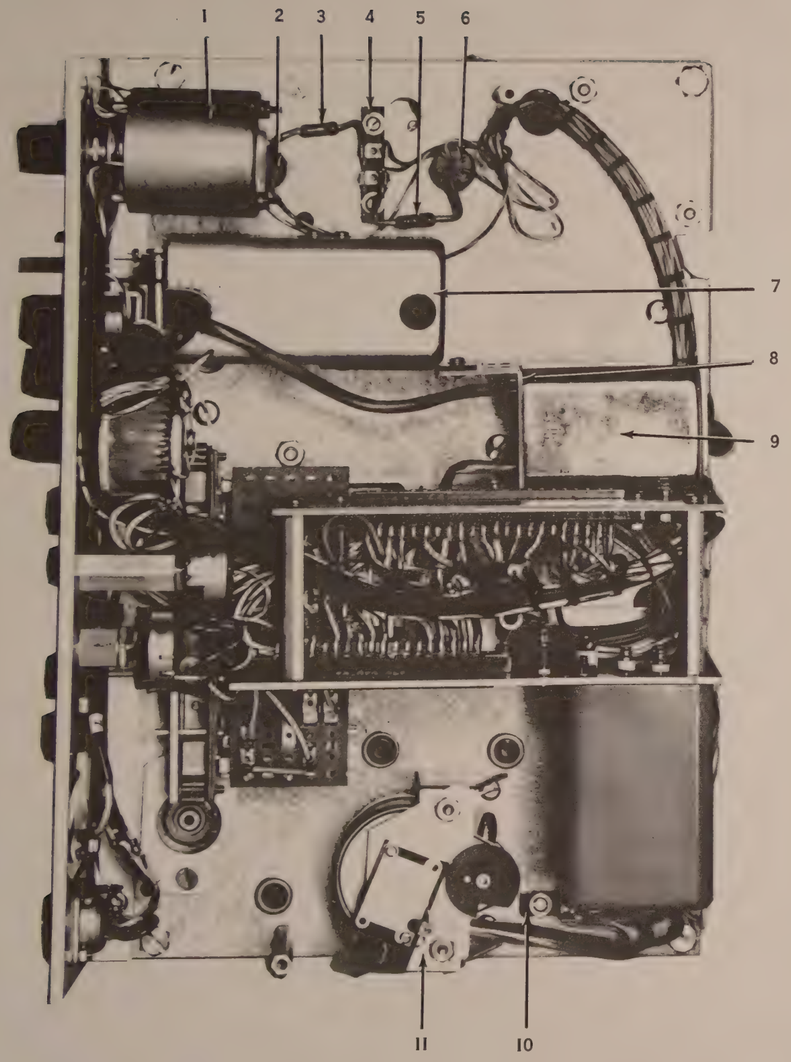


Figure 4-11.
Recorder Model 320
Right Side View

REF. NO.	DESCRIPTION
1	Shield Can
2	Trans. power H5G1 (Q18B)
3	7.5 Ohm ± 5% 3 W (R62B)
4	2 Contact Term. Strip (E2)
5	7.5 Ohm ± 5% 3 W (R62B)
6	H5G1 Transistor (Q19B)
7	Calibration Shield Can, Assy.
8	Bracket, Transformer Mounting Pem #4
9	Transformer (J3B) Input 6-32 Lockwasher 6-32 Hex Nut
10	Terminal Strip, 4 Con. (E1)
11	Timer Assy 60 Cycle Timer Assy 50 Cycle (SEE FIGURE 4-14)

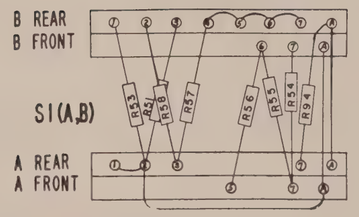


Figure 4-12. SWITCH ASSEMBLY
320-100-C3

FERENCE NO.	DESCRIPTION
S1	Switch, 7 Position Wafer
R54	Resistor 2750 1/4W 1%
R55	Resistor 3470 1/4W 1%
R56	Resistor 10.4K 1/4W 1%
R57	Resistor 50K 1/4w 1%
R58	Resistor 100K 1/4W 1%
R53	Resistor 23.6K 1/4W 1%
R51	Resistor 10K 1/4W 1%
R94	Resistor 43.5K 1/4W 1%
	Attenuator Shield Assy.

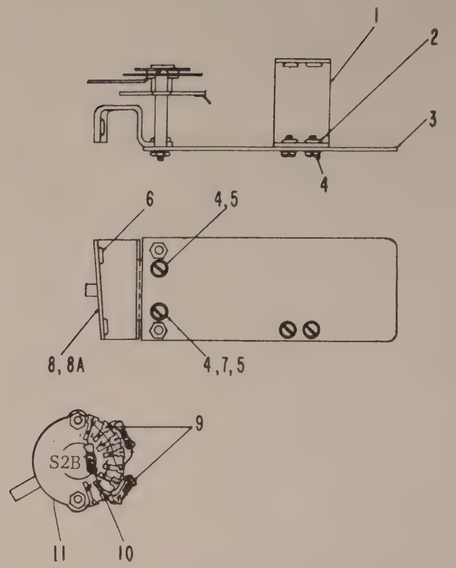


Figure 4-13. RIGHT CAL ASSEMBLY
320-100-C10

REFERENCE NO.	DESCRIPTION
1.	Bracket, cal. Assembly, Mounting
2.	Pem No. 4-40
3.	Printed Board Assy. (SEE FIGURE 4-31)
4.	Sems, No. 4-40 x 1/4 Long
5.	Hex Nut No. 4
6.	Pem No. 4-40
7.	Ground Lug Deleted
8.	Bracket, Right CAL Assembly Mounting
8A.	Bracket, Left CAL Assembly Mounting
9.	Resistor, 500K 1/4W1% (R46B, R50B)
10.	Resistor, 10.2K 1/4W 1% (R49B)
11.	Switch, Lever (S2B)

NOTE: Left CAL Assembly, 320-100-C11, same except:
R49B becomes R49A
R46B becomes R46A
R50B becomes R50A
S2B becomes S2A

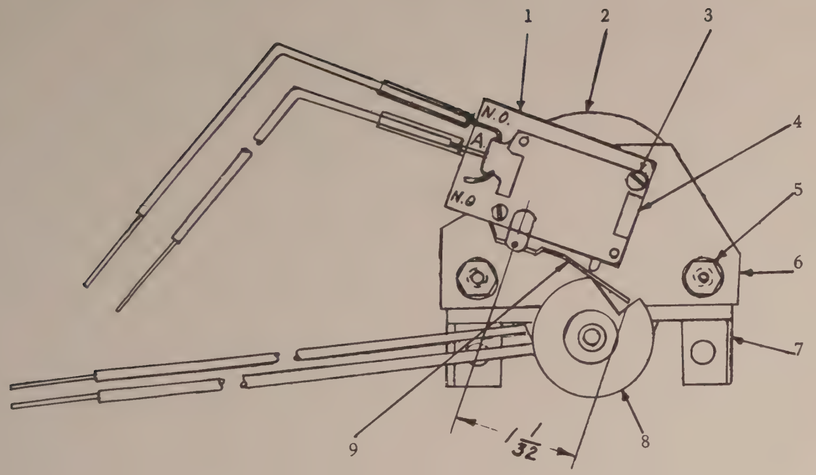


Figure 4-14. TIMER ASSEMBLY
60 CYCLE 152-1300B-C2P5
50 CYCLE 152-1300B-C2P6

REF. NO.	DESCRIPTION
1	Power switch insulator
2	Synchronous motor (60 cycle)
3	#2-56 x 7/16 lg. sems unit
4	SPDT coin switch
5	#6-32 x 1/2 lg. sems unit #6-32 hex nut Internal lock washer Flat washer #6-32 pems
6	Timer switch plate
7	Timer mtg. bracket
8	Timer cam assembly
9	Micro switch act-ator

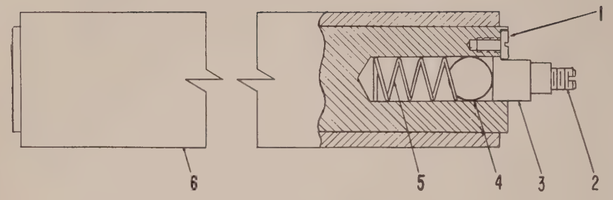


Figure 4-15. **RECORDER BRAKE ROLL ASSEMBLY** 320-100-C20

REFERENCE NO.	DESCRIPTION
1.	4-40 x 3/16 Long Bnd. Hd. Sc.
2.	1/2 Set Screw Sloted Cup Point
3.	Pivot, Brake Adjustment
4.	3/8 Steel Ball
5.	Spring, Brake
6.	Brake Roll Assembly

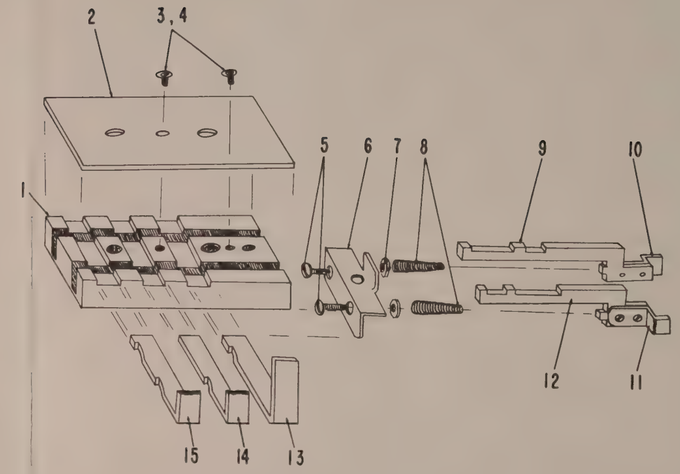


Figure 4-16. **CLUTCH ACTUATOR ASSEMBLY** 320-100-C27

REFERENCE NO.	DESCRIPTION
1.	Support, Clutch Actuator
2.	Plate, Clutch Actuator Bearing
3.	4-40 x 5/16 Sems
4.	No. 4 Flat Washer
5.	6-32 x 3/8 Sems
6.	Bracket, Actuator Spring
7.	No. 6 Hex Nut
8.	Spring
9.	Actuator, Clutch (lower)
10.	Bracket, Actuator Adjust (lower)
11.	Bracket, Actuator Adjust (upper)
12.	Actuator, Clutch (upper)
13.	Cam (5MM)
14.	Cam (20MM)
15.	Cam (100MM)

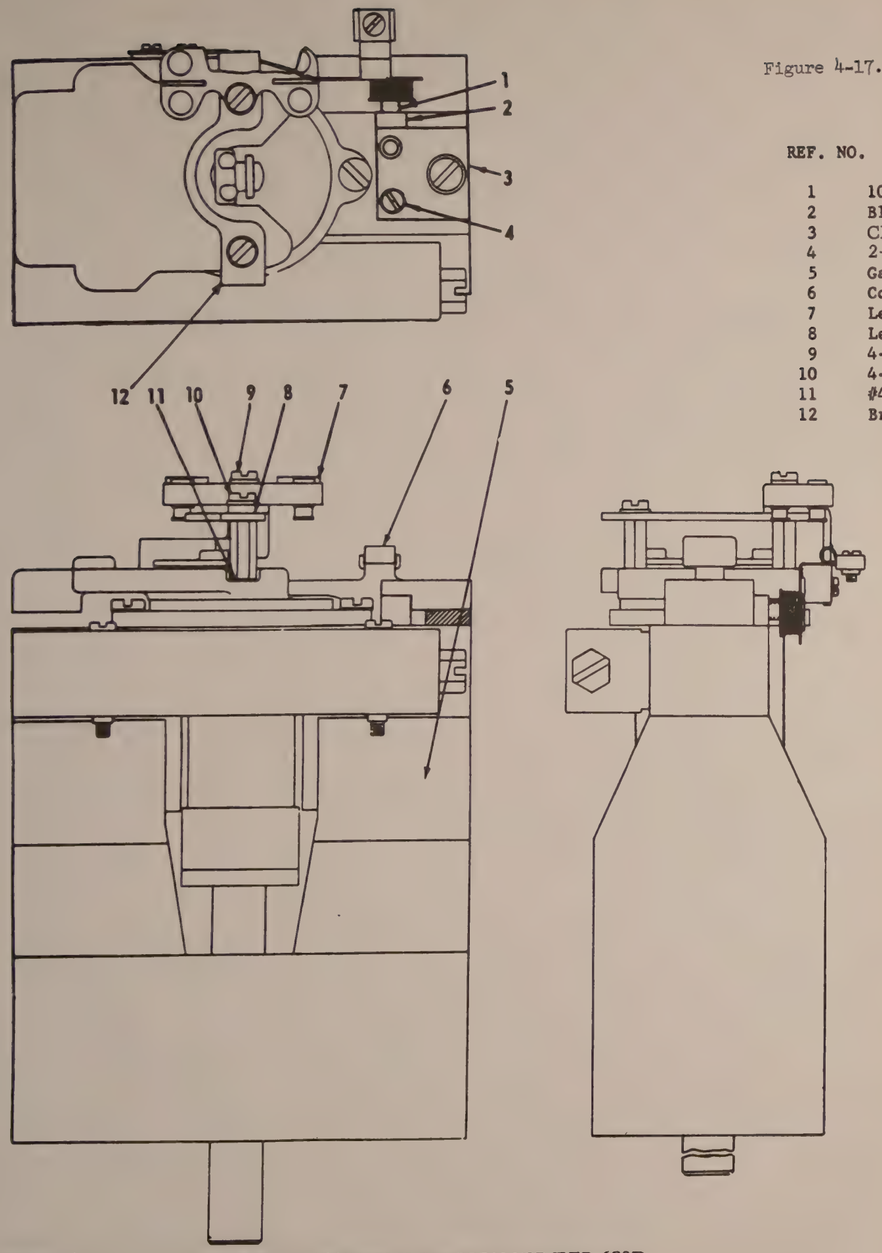


Figure 4-17. GALVANOMETER ASSEMBLY SANBORN NUMBER 608D

REF. NO.	DESCRIPTION
1	10-32 x 1/2 long set scr.
2	Block, adjust lead marker
3	Clamp, L.M. Post
4	2-56 x 1/4 sem
5	Galvy assy. (SEE FIG. 4-18)
6	Coil & stylus holder assy.
7	Lead marker board assy.
8	Lead marker support
9	4-40 x 7/16 sem
10	4-40 x 5/16 sem
11	#4 int. lock washer
12	Bridge

Figure 4-18. GALVANOMETER ASSEMBLY SANBORN NUMBER 607

REF. NO.	DESCRIPTION
1	#4-40 sems x 5/16 long
2	Shunt block
3	Shunt step block
4	#4-40 sems x 7/8 long
5	Cover, shunt
6	Assembly, shunt adjustment
7	Assembly, galvy (SEE FIG. 4-19)
8	Permanent magnet assembly
9	Galvanometer Connector Cable

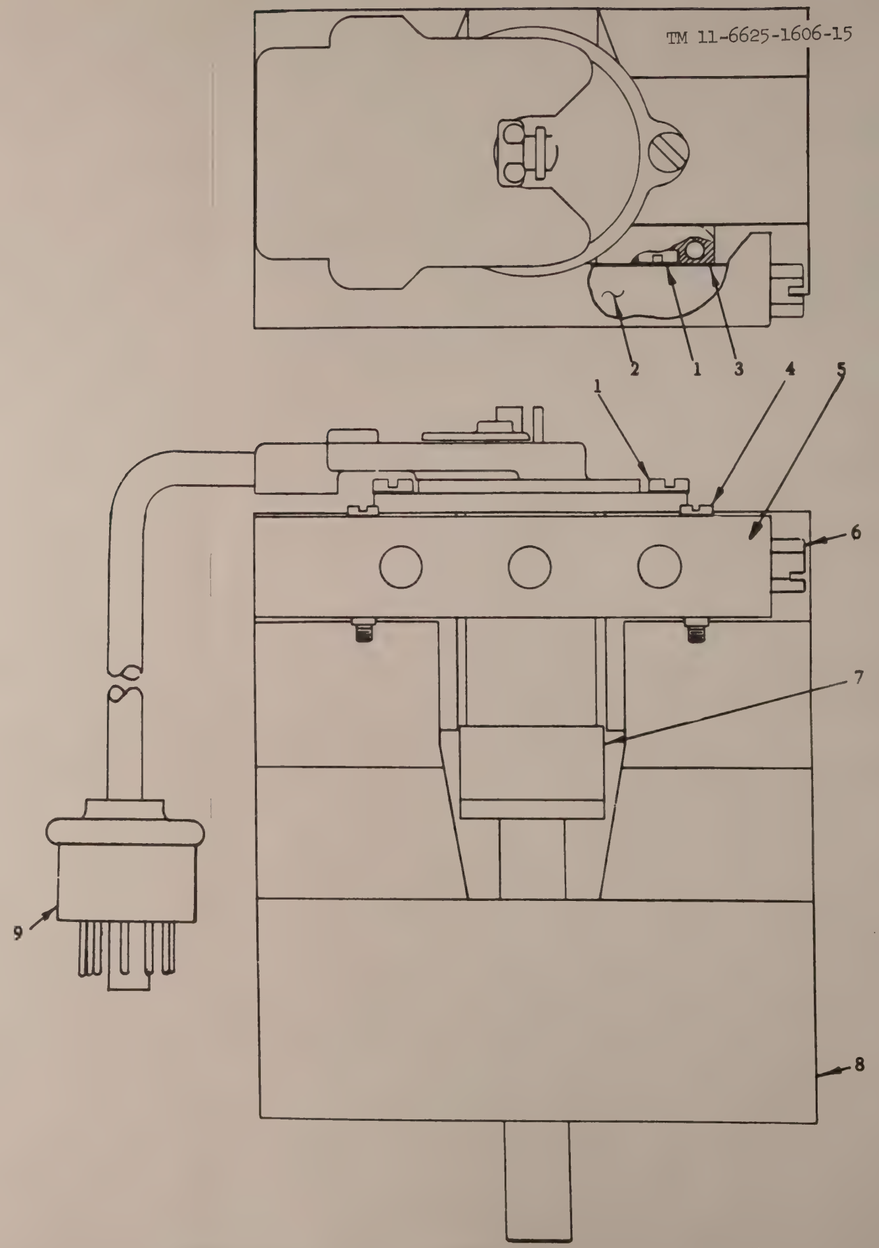


Figure 4-18. GALVANOMETER ASSEMBLY SANBORN NUMBER 607

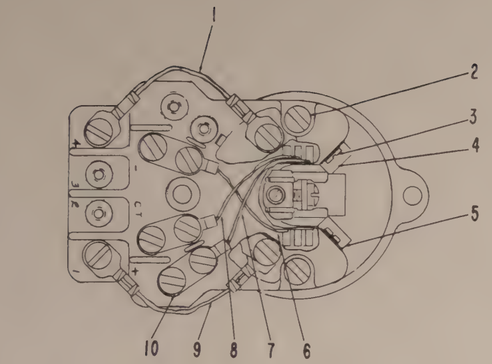
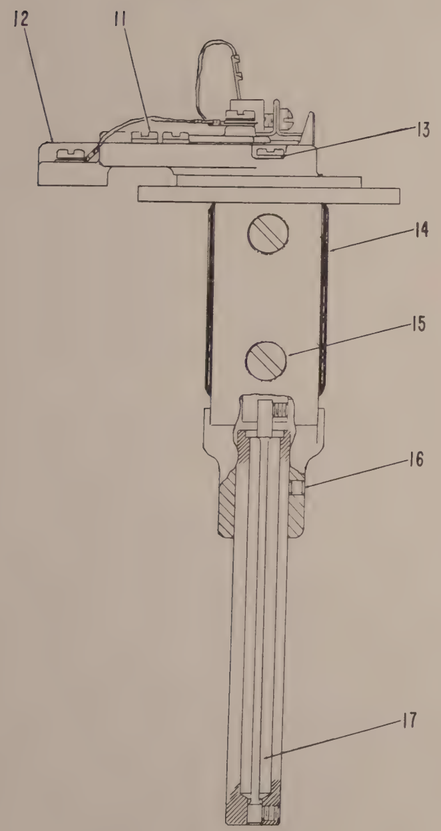


Figure 4-19. GALVANOMETER ASSEMBLY (INSERT) 606

REFERENCE NO.	DESCRIPTION
1.	Jumper
2.	4-40 x 7/16 Long Sem
3.	2-56 x 1/8 Long Sem
4.	Stop
5.	Stop
6.	Pigtail and Lug Assembly
7.	Pigtail and Lug Assembly
8.	Pigtail and Lug Assembly
9.	Jumper
10.	4-40 x Long Machine Screw
11.	4-40 x 1/4 Long Sem
12.	Galvy Cap Assembly
13.	Plain Washer
14.	Galvy Coil Assembly
15.	8-32 x 5/16 Long Sem
16.	4-40 x 1/8 Long Allen Head S.S. Cup Point
17.	Torsion Rod
18.	Galvy Cover
19.	Stylus Mounting Adapter Assembly
20.	Grip ring
21.	Center Block
22.	Sleeve Assembly
23.	Galvy Coil Housing



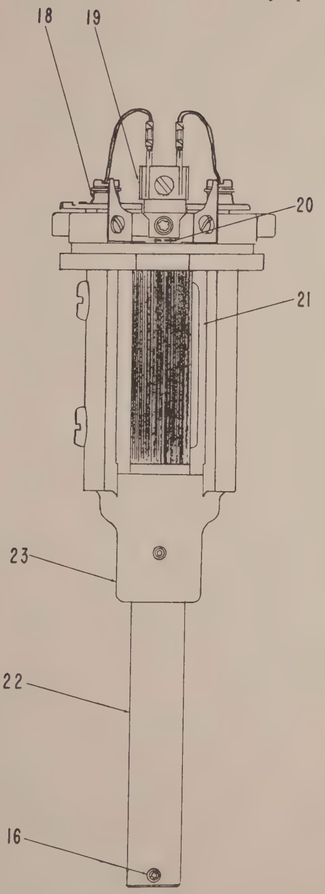
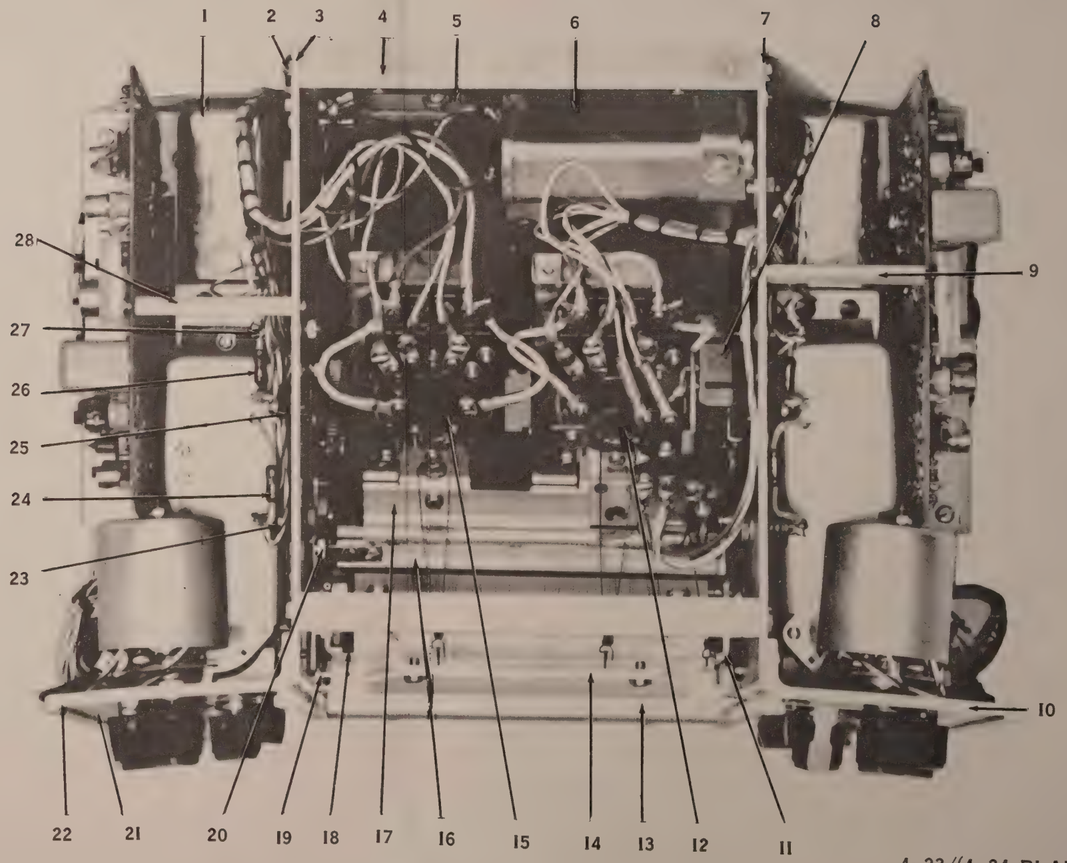


Figure 4-20.
Recorder, Model 320,
Top View

REF. NO.	DESCRIPTION
1	Transformer (T3A)
	Chassis, Upper Left
	Bkt. Transformer Mounting
	6-32 Lockwasher
	6-32 Hex Nut
	Hex Nut #4
	4-40 x 3/8 Sems
	Pem #4
	Eyelet
	Pem #4
2	Shoulder Screw #10
3	Side Plate, Left
4	Spacer, Side Plate
5	Galvy Mounting Plate
6	Capacitor, 2.5 Mfd, 330V(C22)
	8-32 x 5/16 Sems
	8-32 Hex Nut
7	Side Plate, Right
8	Clutch Actuator Assy. (SEE FIGURE 4-16)
9	Spacer, Hex (2)
10	Panel, Right Control
	Insert, Right Panel
11	Paper Drive Table
12	Galvy With Lead Marker (SEE FIGURE 4-17)
13	Shield, Pressure Roll
14	Spring Window
15	Galvy Assy. (SEE FIG. 4-18)
16	Hinge, Male
17	Hinge, Female
18	Platen
19	Table Lock
	Spring
	Stud, Table Lock
20	Stylus Lifter Assembly
	Bracket Stylus Lifter
	Link, Stylus Lifter (lg. arm)
	Pivot, Stylus Lifter Link
21	Insert, Left Panel
22	Panel, Left Control
23	Trans, H5G1 (Q19A)
24	7.5 Ohm ± 5% 3 W (R63A)
25	2 Contact Terminal Strip (E3)
26	7.5 Ohm ± 5% 3 W (R62A)
27	Trans. H5G1 (Q18A)
28	Spacer, Hex



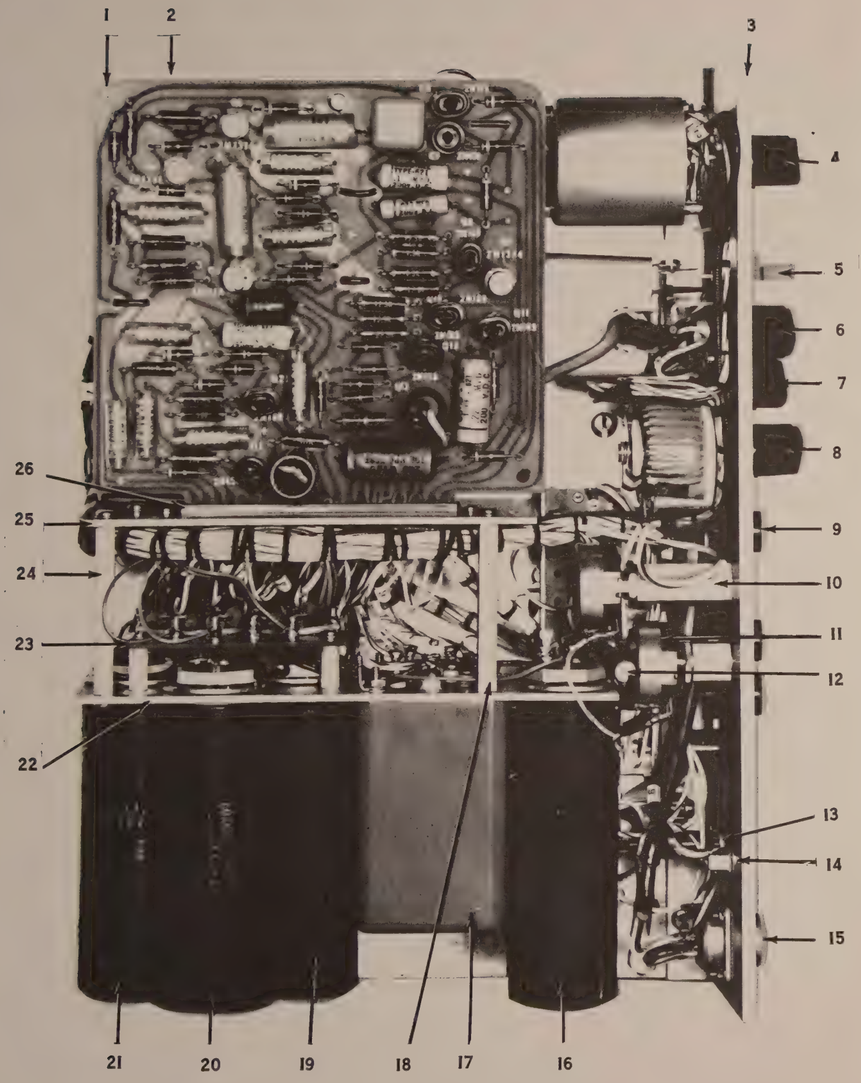


Figure 4-21.
Recorder, Model 320,
Left Side View

REF. NO.	DESCRIPTION
1	Printed Circuit Board Assy. (SEE FIGURE 4-29)
2	Side Plate, Left
3	Panel, Left Control
4	Switch Assy (S1A) (SEE FIGURE 4-12)
	Shield Can.
	Skirted Knob
5	Right Calibration Assy. (S2A) (SEE FIGURE 4-13)
	Knob, Switch Lever
	Washer, Nylon #4
	Screw, 3/8 x 4-40
	Calibration Card Assy. (SEE FIGURE 4-31)
6	Pot 250K (R60A)
	Knob, 1/8 Shaft
	Lug, 1/4 Hole
7	Pot 15K (R52A) Gain
	Lug, Pot
	Knob, 1/4 Shaft
8	Pot .5 Ohm 12.5 W (R70)
	Lug, Pot
	Knob, 1/4 Shaft
9	Push Switch 5 Button (S4)
	.01 Mfd. Disc (C37)
	Push Button Switch Bracket
	Knob, Push Switch
10	Pot. 200 Ohm (R64A)
	Pot Standoff
	Bushing
11	Pot, 5K (R61A)
	Pot Standoff
	Bushing
	Lug, Pot
12	.047, 200V Cap. (C36A)
13	Lamp Assembly (I1)
14	Phone Jack, (J3A)
15	3 Pin Male Connector (J1A)
	3/8 x 4-40 Screw
	Lockwasher #4
	Hex Nut #4
	Nylon Washer #4
	Lug, Right Angle
16	1900 Mfd, 25V Cap. (C21)
17	Transformer (T4)
	Lug, Right Angle
18	Spacer
	6-32 Lockwasher
	6-32 Hex Nut
19	1900 Mfd. 25 V (C19)
20	1900 Mfd, 25 V (C20)
21	1900 Mfd, 25 V (C18)
22	Bracket, Lower Left Side
23	Diode Mtg. Board Assy. (E4) (SEE FIGURE 4-27)
	1/4 x 4-40 Sems
24	Spacer
	3/8 x 6-32 Sems
25	Chassis, Upper Left Side
26	22 Pin Printed Circuit (J2A)

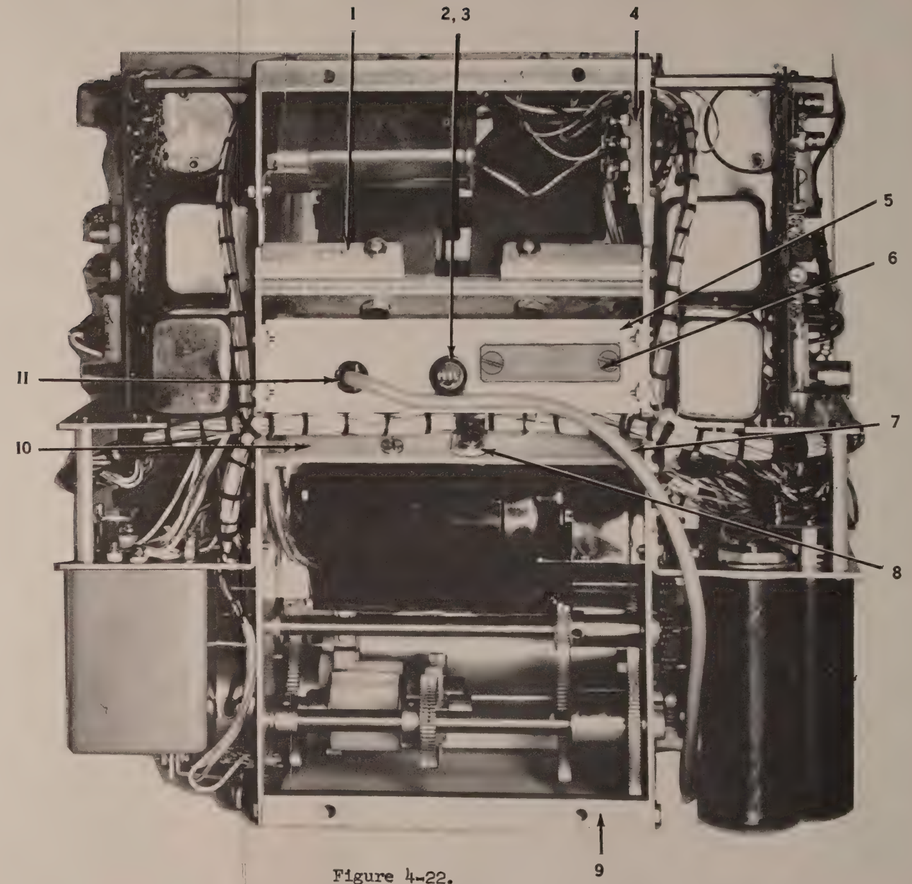
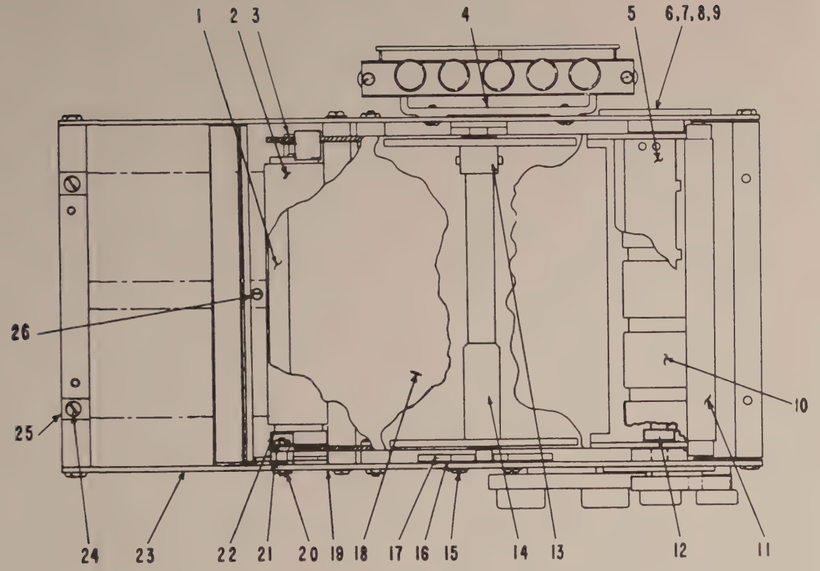
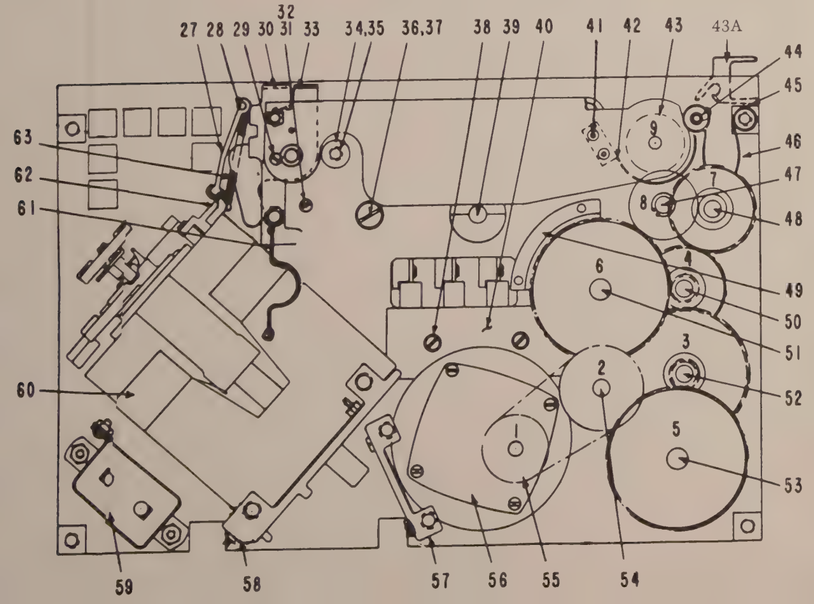
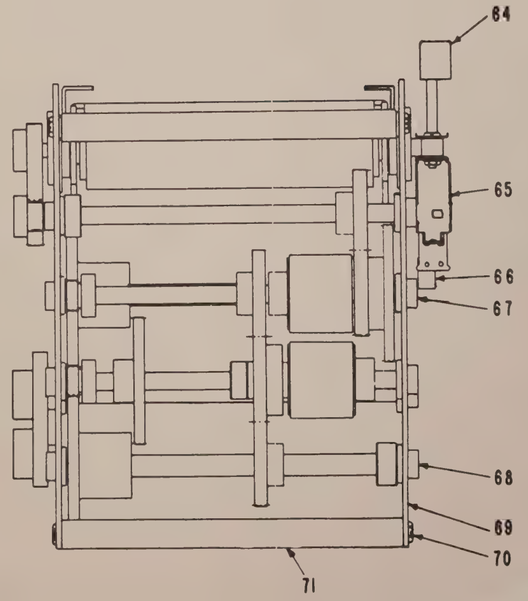


Figure 4-22.
Recorder, Model 320
Back View

REF. NO.	DESCRIPTION
1	Galvy Mounting Plate
2	Fuse Holder
3	1 Amp Slow Blow (F1)
4	3 Contact Terminal Strip (E5)
	4-40 x 3/8 Sems
5	Bracket, Fuse
	Pem #6
	Pem #2
	Sems 6-32 x 3/8
6	Nameplate
	Sems 2-56 x 3/16
7	Plug and Cord Set
8	Cable Clamp
	6-32 x 3/8 Sems
9	Side Plate Spacer
10	Motor Mounting Plate
11	Strain Relief Clamp







REF. NO.	DESCRIPTION
1	Platen
2	Brake Roll Assy. (SEE FIG. 4–15)
3	Bearing Oilite (Flanged)
4	Bracket, Switch Mounting
5	Paper Guide Assembly
	Paper Guide
	Rivet
	Spring Paper Guide
6	Retainer, Drive Roll Bearing
7	Retaining Ring
8	Bearing (Ball)
9	8-32 FH, Mach. Screw
10	Drive Roll Assembly
11	Pressure Roll
12	Drive Roll Spacer
13	Paper Spool Disc, Hub Assy and Spindle Assy.
	Consists of:
	Paper Spool Disc & Hub
	Consists of:
	Paper Spool Spindle
	Roll Pin
14	Paper Spool Hub & Disc Assy
15	8-32 x 5/16 Sems
16	Paper Supply Spring
17	Spindle Support (L.H.)
18	Paper Drive Table
19	Table Lock Stud
20	Shoulder Pivot Screw
21	14 Washer (Used as Spacer)
22	Pivot Assy.
	Consists of:
	Roll Pin
	Shoe Brake
	Brake Roll Pivot
	Brake Shoe Housing
23	Upper Left Chassis
24	8-32 x 3/4 Sems
25	Bracket

REF. NO.	DESCRIPTION
26	Table Latch Spring
27	Male Hinge
28	Rod
29	1/8 6-32 Screw
30	Table Lock & Striker Assy
	Consisting of:
	Striker
	Table Lock
31	6-32 x 5/16 Sems
32	8-32 Hex Nut
33	Table Lift
34	Side Plate Spacer (Round)
35	8-32 x 3/16 Sems
36	Table Stop
37	8-32 Nut (Hex)
38	6-32 x 3/4 Sems
39	Support Spindle (RH)
40	Clutch Actuator Assy (SEE FIGURE 4–16)
41	4-40 x 3/16 Sems
42	Guide Paper Drive Roll
	4-40 x 3/16 Sems
43	Gear 48T-48P
	8-32 x 1/8 Lg. Screw
43A	Shield Pressure Roll
44	Bearing
45	Side Plate Spacer
46	Pressure Roll Spring
47	Stud Shaft
	Ring Retainer
	Washer Spacer
	Gear 60T-48P
	10 Lockwasher Hex Nut
48	#7 Shaft
	24T-48P Gear
	Spacing Washer
	Collar
	72T-48P Gear
	8-32 x 1/8 Lg. Screw
49	Cover Gear
	6-32 x 3/16 Sems

REF. NO.	DESCRIPTION
50	#4 Shaft
	Washer Spacing
	24T-48P Gear
	72T-48P Gear
	Shaft Adapter
	Sleeve 8 Teeth
	Spring
	Clutch Hub Assembly
	Consisting of:
	Hub Assembly
	Hub
	Bearing Oilite OD .43
	ID .31
	Gear
	1/4 x 8-32 Lg. Screw
	Parkerized
	Gear
	8-32 x 1/8 Lg. Screw
51	Shaft #6
	Spacer Washer
	120T-48P Gear
	Over Running Clutch
	24T-40P Gear
	Spacer Washer
	8-32 x 7/8 Lg. Screw
	6-32 x 1/8 Lg. Screw
52	Shaft #3
	Spacing Washer
	24T-48P Gear
	180T-48P Gear (60 cycles)
	90T-42P Gear (50 cycles)
	Collar
	Clutch Hub Assembly
	Consisting of:
	Hub Assembly
	Hub
	Bearing Oilite OD .43
	ID .31
	1/4 x 8-32 Screw
	Parkerized
	48P-72T Gear
	Spring
	Sleeve, 8 Teeth
	Shaft Adapter
	Spacer
	8-32 x 1/8 Lg. Screw
53	Shaft #5
	Washer Spacing
	120T-48P Gear
	Over Running Clutch
	72T-48P Gear
	Collar
	6-32 x 1/8 Lg. Screw
	8-32 x 1/8 Lg. Screw
54	Shaft #2
	Sprocket
	Spacer (.906 Long)
	36T-48P Gear (60 cycles)
	36T-42P Gear (50 cycles)
	8-32 x 1/8 Lg. Screw
55	Sprocket, 3/16 P-20T
	8-32 x 1/8 Lg. Screw
	Chain Steel Drive
56	Motor (Mot-1) 60 cycles
	Motor (Mot-1) 50 cycles
57	Motor Mounting Plate
	8-32 x 7/16 Sems
	10-32 Slot Screw 1/2 Lg.
	10-32 Slot Screw 3/8 Lg.
58	Galvy Mounting Plate
	8-32 x 7/16 Sems
59	Capacitor, 2.5 Mfd. 330V
	8-32 x 5/16 Sems
	8-32 Hex Nut
60	Galvy Mounting Plate
	GALVY (SEE FIGURE 4–18)
	Galvy with Lead Marker (SEE FIGURE 4–17)
61	Table Lock Spring
62	Hinge Female
63	Table Latch Spring
64	Push Switch Knob
65	Switch (S3)
66	Cam and Switch Clamp
67	Deleted
68	Deleted
69	Lower Right Chassis Assy. (SEE FIGURE 4–33)
70	#10 Shoulder Screw
71	Side Plate Spacer

Figure 4-23. RECORDER ASSEMBLY

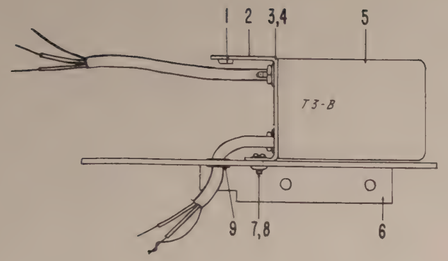


Figure 4-24.

Upper Right Chassis Assembly, 320-100-C7

REF. NO.	DESCRIPTION
1	#4 Pem
2	Bracket, Transformer Mounting
3	6-32 Lockwasher
4	6-32 Hex nut
5	Transformer, T3B
6	Chassis, Upper Right side
7	4-40 X 3/8 Sems
8	#4 Pem
9	Eyelet

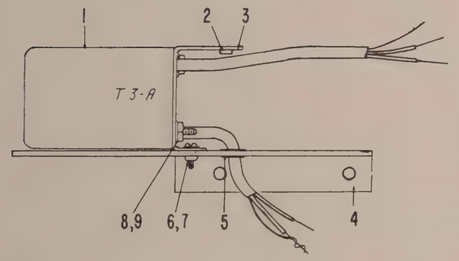


Figure 4-25.

Upper Left Chassis Assembly

REF. NO.	DESCRIPTION
1	Transformer, T3A
2	#4 Pem
3	Bracket, Transformer mounting
4	Chassis, Upper Left side
5	Eyelet
6	4-40 X 3/8 Sems
7	#4 Pem
8	6-32 Lockwasher
9	6-32 Hex nut

Figure 4-26.

Sanborn Dual Channel DC Amplifier, Recorder Model 320, Bottom View

REF NO.	DESCRIPTION
1	Spacer, side plate
2	Spacer, square
3	Guide, paper drive roll
	4-40 X 3/16 Sems
4	Permapaper, Medical
	Permapaper, Industrial
5	Gear Cover
6	Retainer, drive bearing
7	Spacer, side plate
	No. 10 Shoulder screw
8	Motor, 50 cycle, 38B—54 — 60 cycle 38B—37
	Parts on shafts are called from left to right on figure
9	Shaft No. 5
	Spacer
	Gear with hub,120T-48P S.S
	Overrunning miniclutch
	Gear with hub, 72T-48P S.S.
	Collar 3/8 I.D.
	8-32 X 1/8 Lg. Allen hd. cup pt. screw
	Washer, spacing
10	Motor sprocket
11	Drive chain, steel
12	Shaft No. 2 (behind No. 3)
	Sprocket 25T-3/16 P
	8-32 X 1/8 lg. Allen hd. cup pt. screw
	Spacer
	Gear 36T-48P-20° PA
13	Shaft No. 3
	Washer, spacing
	Gear with hub, 24T-48 S.S.
	8-32 X 1/8 Lg. Allen hd cup pt. screw
	Gear, 108T-48P 20°PA.
	8-32 x 1/8 Lg. Allen hd. cup pt. screw
	Collar
	Clutch hub assembly
	Gear, 48P-72T
	Hub assy
	Hub, spring clutch
	Sleeve, clutch spring
	Spring, clutch
	Adaptor shaft
	10-32 X 1/4 Allen hd cup pt
	Spacer
14	Sprocket
	8-32 X 1/4 Allen hd. cup pt. set screw
15	Shaft No. 4
	Gear with hub, 24T-48P S.S.
	8-32 X 1/8 Lg. Allen hd. cup pt. set screw
	Gear with hub, 72T-48P
	Clutch hub assembly
	Hub assembly
	Gear, 48P-72T
	8-32 X 1/4 Soc. hd. Set screw Parkerized
	Gear, 96T-40P 20°PA
	Washer, spacing
16	Shaft No. 6
	Gear with hub, 24T-48P S.S.
	Overrunning Miniclutch
	Gear, spur
	8-32 X 1/8 Lg. Allen hd., cup pt. set screw
17	Shaft No. 7
	Gear with hub, 24T-48P S.S.
	8-32 X 1/8 Lg. Allen hd., cup pt. set screw
	Collar
	8-32 X 1/8 Lg. Allen hd. cup pt. set screw
	Gear with hub 72T-48P 20°PA
	Washer, spacing
18	Stud shaft
	Retainer ring, external 5/16
	10-32 Hex nut
	Gear, 60T-48P-20°PA
19	Gear, 48T-48P-20°PA

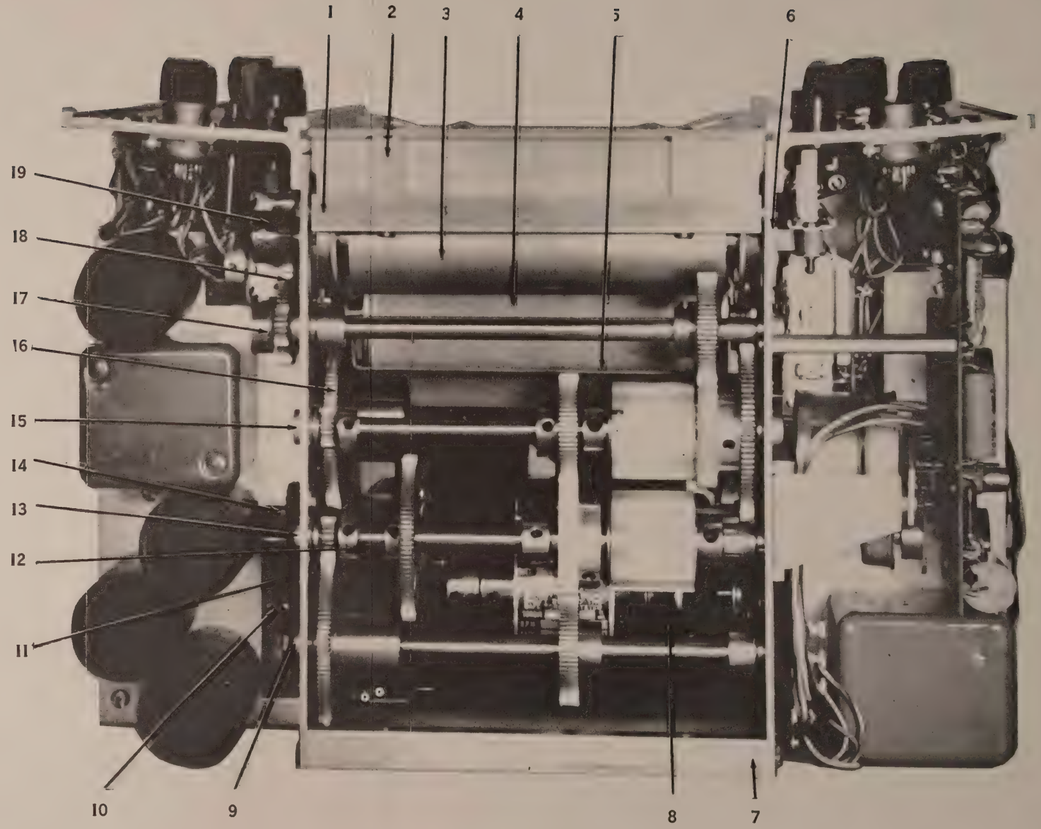


Figure 4-26.

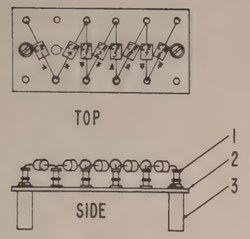


Figure 4-27.

Diode Mounting Board Assembly (E4) 320-100-C2

REF. NO.	DESCRIPTION
1	Turret Lugs
2	Terminal Board
3	4-40 X 1/4 Sems
4	Spacer
CR1 thru CR8	Rectifier 1N2069

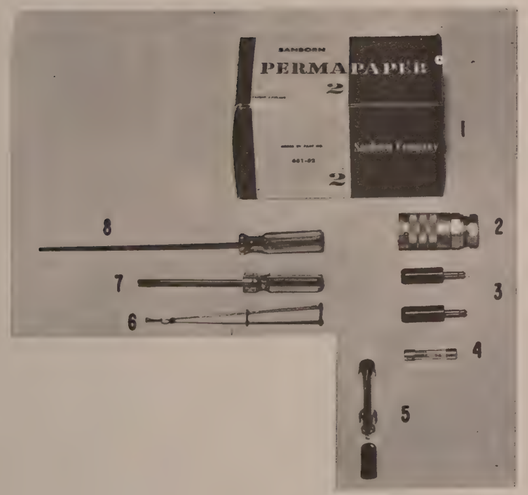


Figure 4-28.

Accessories Supplied

With Sanborn Recorder, Model 320

ITEM	DESCRIPTION	AMT.
1	Permapaper Industrial	1
	Permapaper Medical	1
2	*12 Contact Female Plug	1
3	Plug, Miniature Phone	2
4	Fuse, 1 Amp. Slow Blow	1
5	Stylus Pressure Tester	1
6	Writing Arm	2
7	Screwdriver (Stylus Pressure)	1
8	Spline Wrench Assembly	1
	*Changed to 3 Contact Female	2
	3 Wire Adapter	1
	Rubber Bushing	2

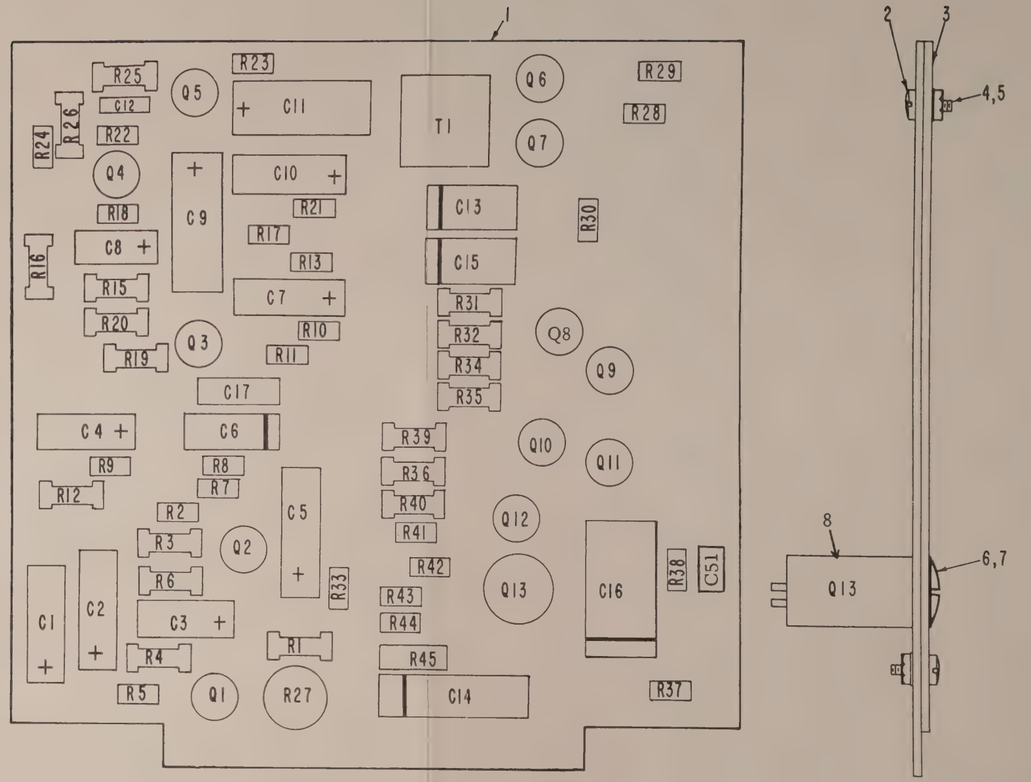


Figure 4-29. MEDIUM GAIN PREAMPLIFIER CARD, 950-3400

REF. NO.	DESCRIPTION
1	Printed Board (machined)
2	4-40 x 3/8 Screw
3	Backing Strip and Shield
4	#4 Lockwasher
5	#4 Hex Nut
6	#8 Ext. Lockwasher
7	8-32 x 3/16 Screw
8	Transistor Heat Sink

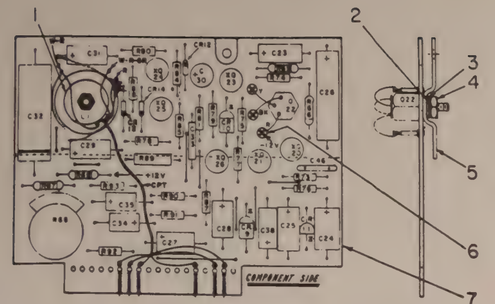


Figure 4-30. REGULATOR CARD 321-100-C10

REF. NO.	DESCRIPTION
1	Hex Nut 4-40 Washer, Fiber Lockwasher #4 Screw 4-40 x 3/4" Long
2	Washer, Flat
3	Lockwasher #10
4	Hex Nut 10-32
5	Heat Sink
6	Turret Lug (Long)
7	Printed Board (Machined)

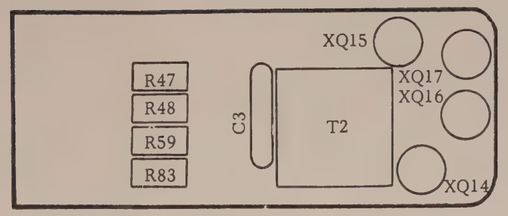


Figure 4-31. PRINTED CIRCUIT ASSEMBLY 320-100-C30

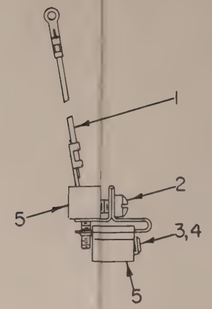


Figure 4-32. STYLUS MOUNTING ADAPTER 613-100-C7

REF. NO.	DESCRIPTION
1	Pigtail Assy.
2	#4-40 NC-3x 3/16 Lg. Fil. Hd. S.S. Sc.
3	#8-32 x 3/16 Lg. Set Screw
4	Shoe
5	Adapter & Spring Assy. Consisting of: Spring Stylus Mtg. Adapter Machine Screw 1/4 x1/72 Fil. Hd.
6	Clamp

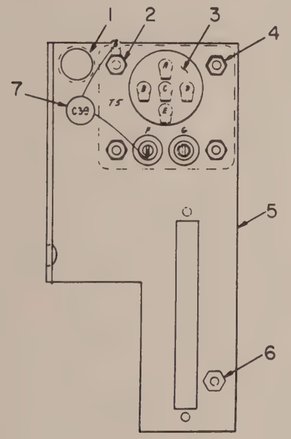


Figure 4-33. LOWER RIGHT CHASSIS ASSEMBLY 320-100-C6

REF. NO.	DESCRIPTION
1	Eyelet
2	Lug, Right Angle Hex Nut 6-32 Lockwasher 6-32
3	Transformer
4	Spacer
5	Chassis, Lower Right Side
6	3/8" 6-32 Sems Spacer
7	Capacitor .01 MFD. Disk

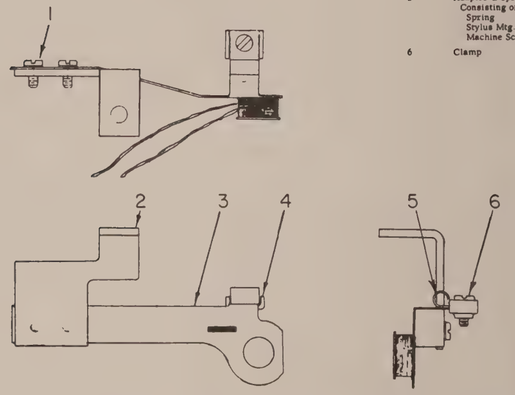


Figure 4-34. COIL AND STYLUS HOLDER ASSEMBLY 608D-100-C3

REF. NO.	DESCRIPTION
1	#2-56 Sem x 3/16 Long
2	Bracket, Coil Holder
3	Coil Assembly Consisting of: Black Wire x 5" Long Lead Marker Coil Assembly Consisting of: 1200 Turns #44 Wire Bobbin Holder, Coil & Stylus
4	Shoe, Clamp
5	Clamp, Lead Marker
6	#2-56 Sem x 3/16 Long

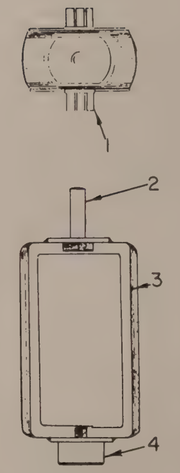


Figure 4-35. GALVANOMETER COIL ASSEMBLY 606-100-C2

REF. NO.	DESCRIPTION
1	Ass'y Galvy Coil Term, Insulation
2	Pivot, Coil
3	Frame, Galvy Coil
4	Bracket, Coil (Lower)

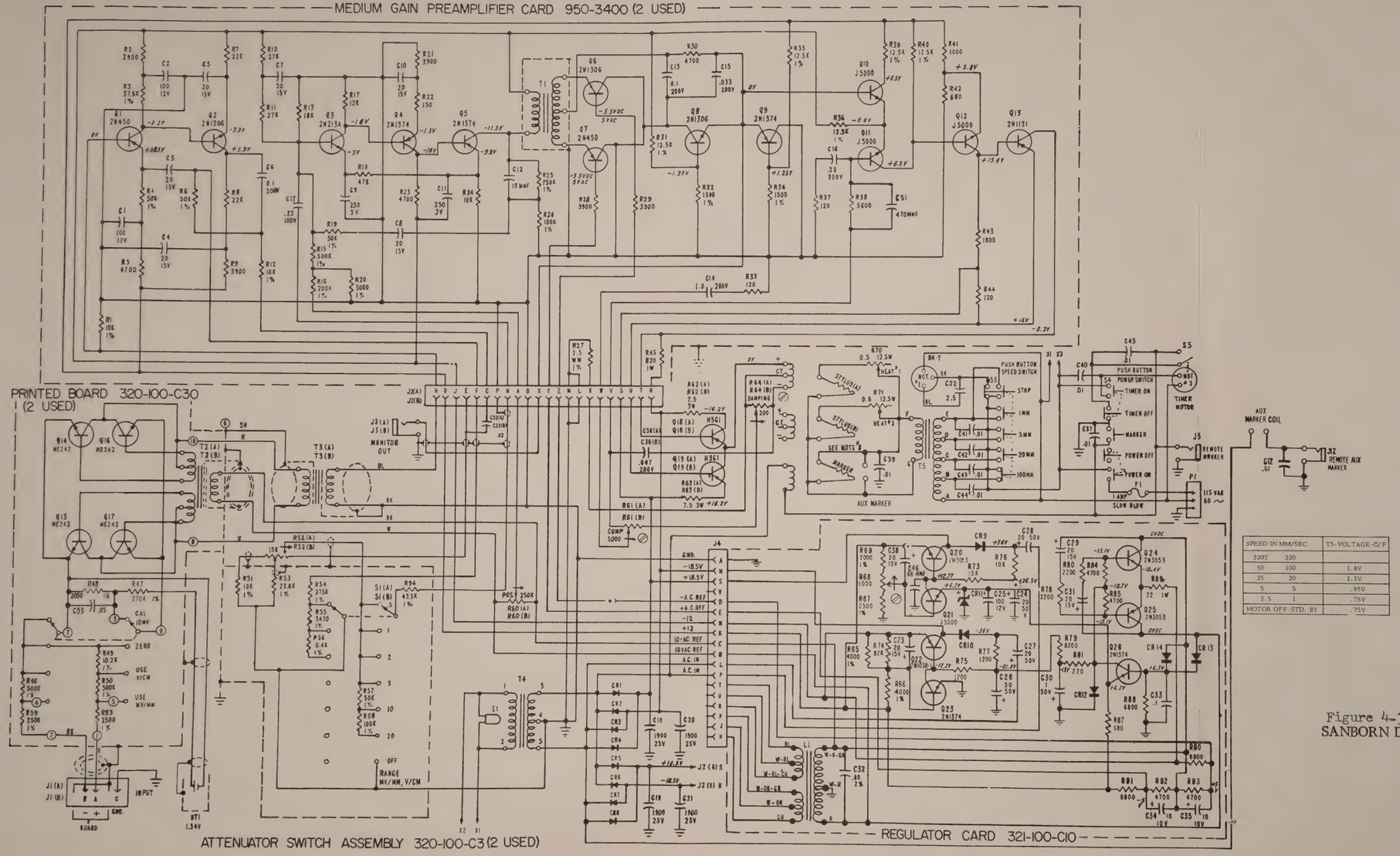


Figure 4-36.
SANBORN DUAL CHANNEL DC AMPLIFIER RECORDER
MODELS 320, 320T
SCHEMATIC: 320-100-C1 SUB 34

APPENDIX A

REFERENCES

DA Pam 310–4	Index of Technical Manuals, Technical Bulletins, Supply Manuals (types 7, 8, and 9), Supply Bulletins, and Lubrication Orders.
DA Pam 310–7	Index of Current Modification Work Orders.
SB 38–100	Preservation, Packaging, Packing and Marking Materials, Supplies, and Equipment Used by the Army.
TB 746–10	Field Instructions for Painting and Preserving Electronics Command Equipment.
TB SIG 222	Solder and Soldering.
TB SIG 355–1	Depot Inspection Standard for Repaired Signal Equipment.
TB SIG 355–2	Depot Inspection Standard for Refinishing Repaired Signal Equipment.
TB SIG 355–3	Depot Inspection Standard for Moisture and Fungus Resistant Treatment.
TM 38–750	The Army Maintenance Management Systems (TAMMS).

APPENDIX B

MAINTENANCE ALLOCATION

Section I. INTRODUCTION

B–1. General

This appendix provides a summary of the maintenance operations covered in the equipment literature.

It authorizes categories of maintenance for specific maintenance functions on repairable items and components and the tools and equipment required to perform each function. This appendix may be used as an aid in planning maintenance operations.

B–2. Maintenance Functions

Maintenance functions will be limited to and defined as follows:

a. INSPECT. To determine serviceability of an item by comparing its physical, mechanical, and electrical characteristics with established standards.

b. TEST. To verify serviceability and to detect incipient electrical or mechanical failure by use of special equipment such as gages, meters, etc. This is accomplished with external test equipment and does not include operation of the equipment and operator type tests using internal meters or indicating devices.

c. SERVICE. To clean, to preserve, to charge, and to add fuel, lubricants, cooling agents, and air. If it is desired that elements, such as painting and lubricating, be defined separately, they may be so listed.

d. ADJUST. To rectify to the extent necessary to bring into proper operating range.

e. ALIGN. To adjust two or more components or assemblies of an electrical or mechanical system so that their functions are properly synchronized. This does not include setting the frequency control knob of radio receivers or transmitters to the desired frequency.

f. CALIBRATE. To determine the corrections to be made in the readings of instruments or test equipment used in precise measurement. Consists of the comparison of two instruments, one of which is a certified standard of known accuracy, to detect and adjust any discrepancy in the accuracy of the instrument being compared with the certified standard.

g. INSTALL. To set up for use in an operational environment such as an encampment, site, or vehicle.

h. REPLACE. To replace unserviceable items with serviceable like items.

i. REPAIR. To restore an item to serviceable condition through correction of a specific failure or unserviceable condition. This function includes, but is not limited to welding, grinding, riveting, straightening, and replacement of parts other than the trial and error replacement of running spare type items such as fuses, lamps, or electron tubes.

j. OVERHAUL. Normally, the highest degree of maintenance performed by the Army in order to minimize time work in process is consistent with quality and economy of operation. It consists of that maintenance necessary to restore an item to completely serviceable condition as prescribed by maintenance standards in technical publications for each item of equipment. Overhaul normally does not return an item to like new, zero mileage, or zero hour condition.

k. REBUILD. The highest degree of materiel maintenance. It consists of restoring equipment as nearly as possible to new condition in accordance with original manufacturing standards. Rebuild is performed only when required by operational considerations or other paramount factors and then only at the depot maintenance category. Rebuild reduces to zero the hours or miles the equipment, or component thereof, has been in use.

l. SYMBOLS. The uppercase letter placed in the appropriate column indicates the lowest level

at which that particular maintenance function is to be performed.

B–3. Explanation of Format

a. Column 1, group number. Column 1 lists group numbers, the purpose of which is to identify components, assemblies, subassemblies and modules with the next higher assembly.

b. Column 2, functional group. Column 2 lists the noun names of components, assemblies, subassemblies and modules on which maintenance is authorized.

c. Column 3, maintenance functions. Column 3 lists the maintenance category at which performance of the specific maintenance function is authorized. Authorization to perform a function at any category also includes authorization to perform that function at higher categories. The codes used represent the various maintenance categories as follows:

Code	*Maintenance Category*
C	Operator/Crew
O	Organizational Maintenance
F	Direct Support Maintenance
H	General Support Maintenance
D	Depot Maintenance

d. Column 4, tools and test equipment. Column 4 specifies, by code, those tools and test equipment required to perform the designated function. The numbers appearing in this column refer to specific tools and test equipment which are identified in table I.

e. Column 5, Remarks. Self-explanatory.

B–4. Explanation of Format of Table I, Tool and Test Equipment Requirements

The columns in Table I, Tool and Test Equipment Requirements are as follows:

a. Tools and Equipment. The numbers in this column coincide with the numbers used in the tools and equipment column of the Maintenance Allocation Chart. The numbers indicate the applicable tool for the maintenance function.

b. Maintenance Category. The codes in this column indicate the maintenance category normally allocated the facility.

c. Nomenclature. This column lists tools, test, and maintenance equipment required to perform the maintenance functions.

d. Federal Stock Number. This column lists the Federal stock number of the specific tool or test equipment.

e. Tool Number. Not used.

MAINTENANCE ALLOCATION CHART

GROUP NUMBER	COMPONENT ASSEMBLY NOMENCLATURE	MAINTENANCE FUNCTIONS											TOOLS AND EQUIPMENT	REMARKS
		INSPECT	TEST	SERVICE	ADJUST	ALIGN	CALIBRATE	INSTALL	REPLACE	REPAIR	OVERHAUL	REBUILD		
1	DUAL CHANNEL DC AMPLIFIER RECORDER, MODEL 320R462-251-2 AND PAPER TAKE UP, 320R-300	F											None	Visual
			H										1 thru 8	
					H								1,2,3,7,8	
										H			1 thru 8	
1A	CIRCUIT CARD ASSEMBLY, 320-100C30	H											None	Visual
			H										3,7	
									H				7	
										H			3,7	
1B	CIRCUIT CARD ASSEMBLY, 950-3400	H											None	Visual
			H										3,7	
									H				7	
										H			3,7	
1C	RECORDER CALIBRATION ASSEMBLY, 321-100 C 10	H											None	Visual
			H										3,7	
									H				7	
										H			3,7	
1D	TIMER ASSEMBLY, 14002 D	H											None	Visual
			H										3,7	
									H				7	
										H			3,7	

TABLE I. TOOL AND TEST EQUIPMENT REQUIREMENTS, MODEL 320R462-251-2 and MODEL 320R-300

TOOL AND TEST EQUIPMENT REQUIREMENTS

TOOLS AND EQUIPMENT	MAINTENANCE CATEGORY	NOMENCLATURE RECOMMENDED IN MANUAL	FEDERAL STOCK NUMBER	TOOL NUMBER
1	H	STYLUS PRESSURE TESTER HEWLETT PACKARD 14023 A		
2	H	MULTIMETER AN/PSM-6 OR TRIPLETT 630 NA		
3	H	AC VTVM HEWLETT PACKARD 400 H		
4	H	VOLTAGE STANDARD AND NULL METER KINTEL 301		
5	H	VOLTAGE DIVIDER GENERAL RADIO 1454A		
6	H	VARIAC GENERAL RADIO W10HM		
7	H	TOOL KIT, ELECTRONIC EQUIPMENT TK-100/G		
8	H	SINE AND SQUARE WAVE OSCILLATOR HEWLETT PACKARD 3300		

By Order of the Secretary of the Army:

W. C. WESTMORELAND,
General, United States Army,
Chief of Staff.

Official:
VERNE L. BOWERS,
Major General, United States Army,
The Adjutant General.

Distribution:

Active Army:

USASA (2)
CNGB (1)
ACSC-E (2)
USAMB (10)
USACDCEC (5)
USACDCCEA (1)
USACDCCEA (Ft Huachuca) (1)
OS Maj Comd (2)
USARV (10)
USARYIS (5)
USATECOM (2)
USAESC (25)
USASTRATCOM (5)
USASTRATCOM-PAC (10)
USASTRATCOM-CONUS (5)
USASTRATCOM SIG GP-T (5)
LOGCOMD (5)
USASUPCOM-CRB (5)
USASUPCOM QN (5)
USASUPCOM-SGN (5)
Eighth USA (10)
1st Sig Bde (10)
SAAD (10)
TOAD (10)
LEAD (7)
Cam Rahn Bay Dep (3)
Long Binh Dep (3)
Qui Nhon Dep (3)
USA ASCOM Dep (3)
Cp Carroll Dep (3)
ICC (3)
USACSA (2)
USASTRATCOM Sig Gp, Japan (3)
USASTRATCOM Comm Op Bn, Korea (2)
Sig FLDMS (pac) (1)
Units org under fol TOE:—2 ea.
11-15
11-45
11-97
11-98
11-158
11-302
11-303
11-347
11-357
11-367
11-368
11-377
11-500(AA-AC)
29-118
29-134
29-136
29-137

ARNG: None.

USAR: None.

For explanation of abbreviations used, see AR 310-50.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1971—714-209/176